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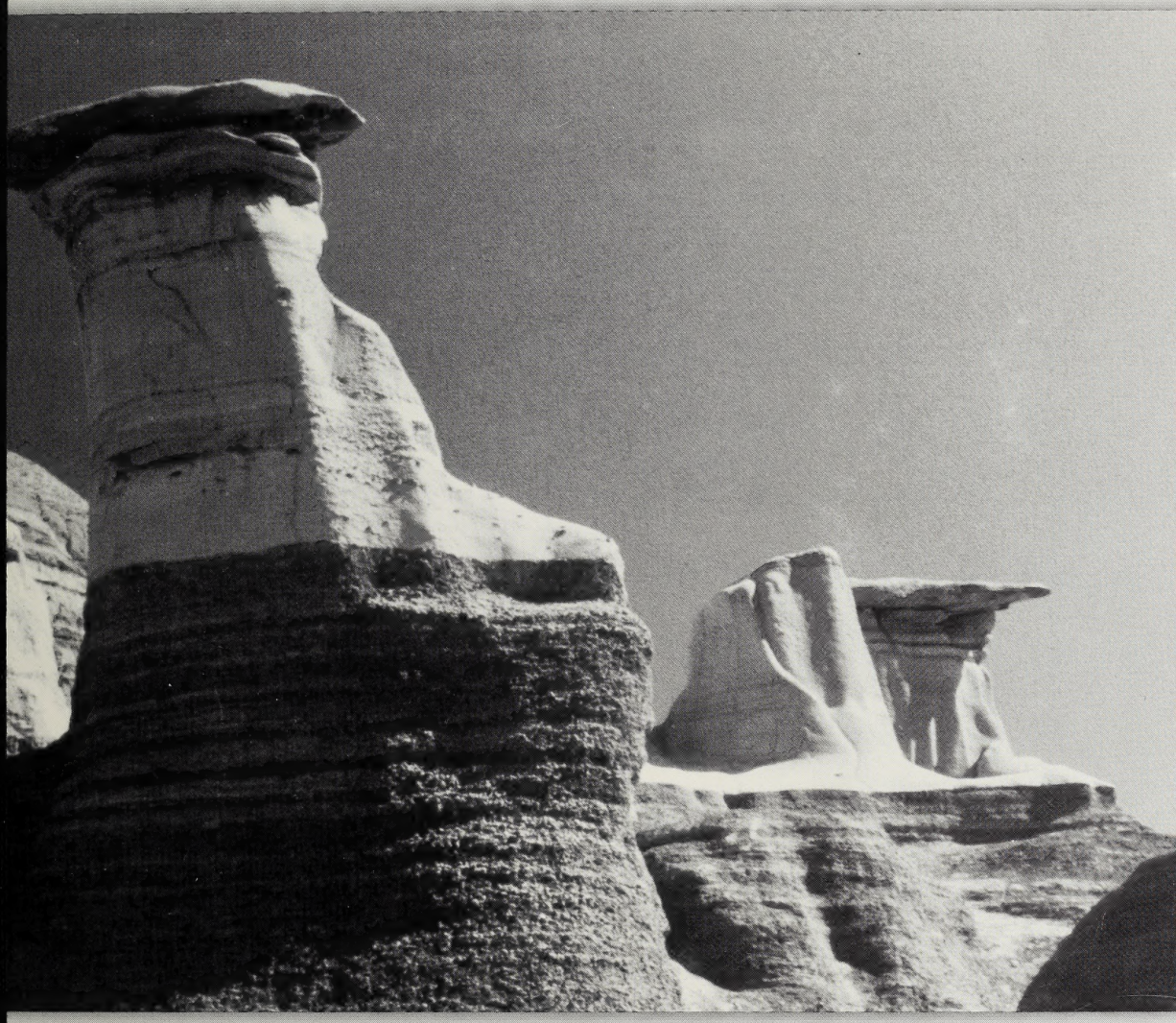

MODULE 2

Life from the Past

Distance Learning

Alberta EDUCATION

JUL 2 6 1994

Science 20

Module 2

Life from the Past

Alberta EDUCATION

Distance Learning

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Science 20
Student Module
Module 2
Life from the Past
Alberta Distance Learning Centre
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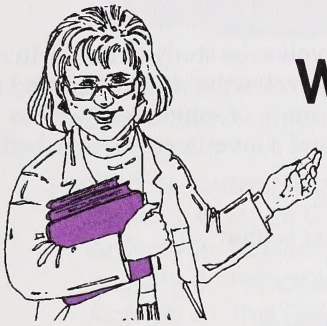
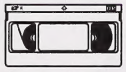


Welcome to Module 2!

We hope you'll enjoy your study of Life from the Past.

To make your learning a bit easier, watch the referenced videocassettes whenever you see this icon.



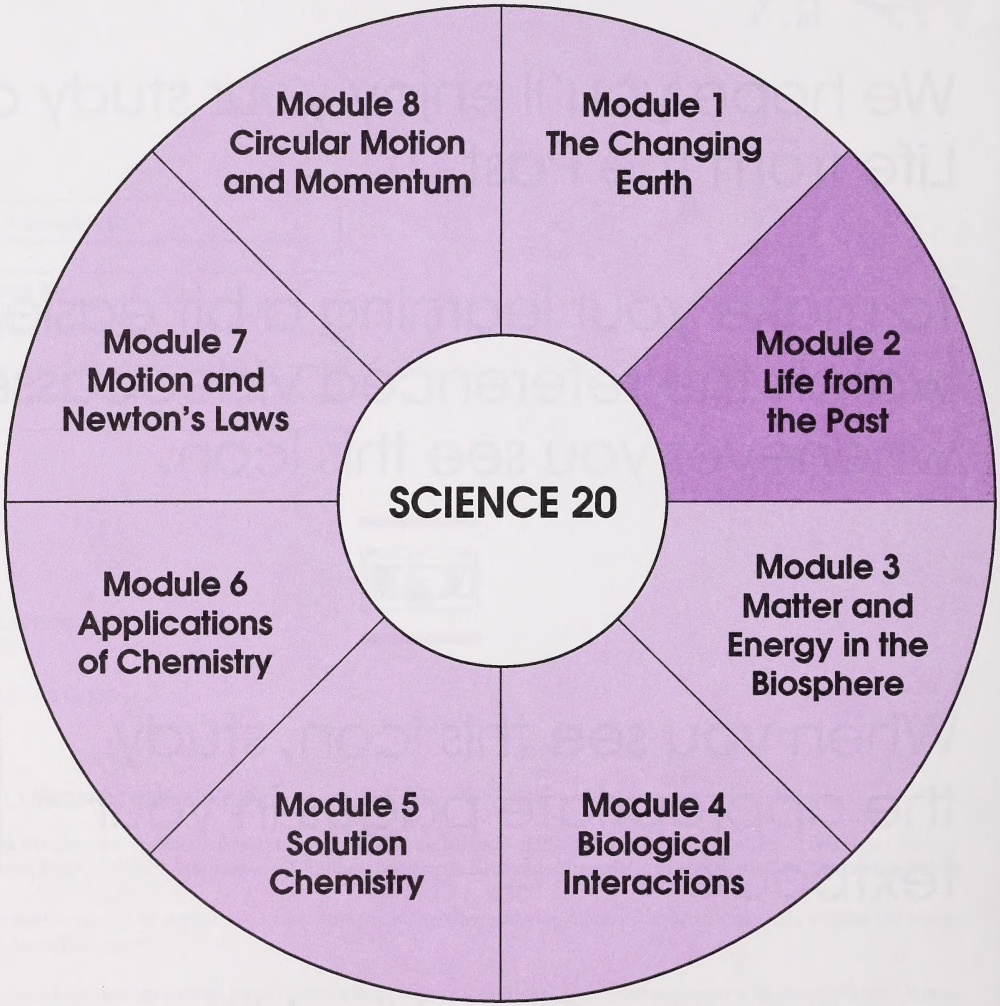
When you see this icon, study the appropriate pages in your textbook.

Good Luck!

COURSE OVERVIEW

This course contains eight modules. Modules 1 and 2 involve the study of the Earth's physical features and past life history. Modules 3 and 4 involve the study of life and its interaction with the Earth. Modules 5 and 6 involve the study of solutions as well as how chemistry is used for everyday things. Modules 7 and 8 investigate motion, both on Earth and in space.

The module you are working on is highlighted in a darker colour.



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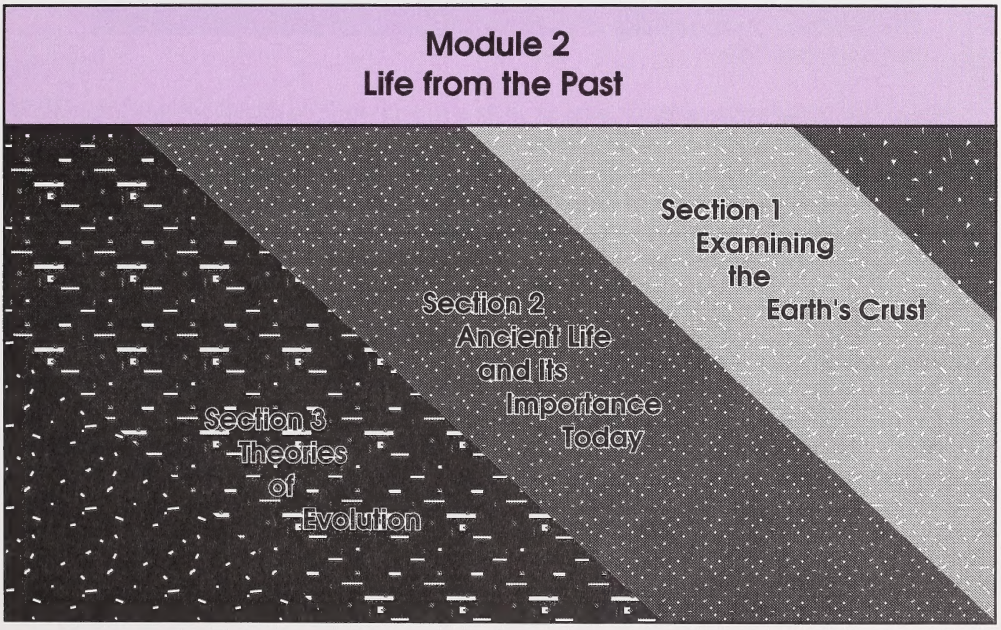
MODULE OVERVIEW

You are on vacation in the foothills of Alberta and have stopped just off the David Thompson highway at a great picnic spot overlooking a rapidly moving stream. A fellow is standing in a shallow bend in the stream sloshing a gold pan around and around. When you go closer to see what he is doing, he shows you some of the fine gold dust he has painstakingly collected that day. You are aware of the Klondike gold rush, and the rich deposits of northern gold that fueled that colourful time in Canada's history. But gold in Alberta's rivers? Where does it come from? How does it collect in river beds?

After lunch you continue your journey deeper into the Rockies. You marvel at the massive uplifts of rock and the folding of the layers that characterize some mountains. And on a hike along one of the paths you find some fossilized shells embedded in one of the rock layers. What is the story of this ancient mountain and its many layers of rock? What are the minerals and fossils and other materials that make up the rock layers?

Rocks contain information that can tell you about past conditions and life on this planet. Some of this information may be used to evaluate the economic worth of geologic resources, such as oil and gas reserves, that may be present in specific areas.

In Module 1 you discovered that the Earth's crust is continuously modified through the movement of plates and the advance and retreat of glaciers. In this module, you are going to learn about the materials found in the Earth's crust, examine the methods used in determining the age of these materials, and investigate the theories of how life has evolved to where it is today.



Evaluation

Your mark in this module will be determined by your work in the Assignment Booklet. You must complete all assignments. In this module you are expected to complete three section assignments. The assignment breakdown is as follows:

Section 1 Assignment	**40 marks**
Section 2 Assignment	**35 marks**
Section 3 Assignment	**25 marks**
TOTAL	**100 marks**

Section

1 Examining the Earth's Crust

COURTESY OF GEORGE MUDRYK

Walking along the beach or shoreline of a river or lake, you have probably bent down and picked up a few rocks that have caught your eye. They may have been incredibly smooth and flat, or shiny and full of crystals, or even made of pieces that look like shells glued together. You may even have seen smaller rocks of different types that look cemented together to form the rock you are holding. How did such a variety of rocks end up in this place? Were most formed in this location? Were some moved here by glaciers or streams?

This section will help you develop skills to identify and classify different types of rocks and understand how they were formed. You will establish how fossils were formed and how they provide scientists with a natural history of living things. You will also develop the methods scientists use to date the age of rocks and fossils and how rock layers are used to study the changes to the Earth's surface over the reaches of geologic time.

Activity 1: Rock Classes and the Rock Cycle

What is a rock? You know from experience that there is a huge variety in types of rock. So what is the best way to define *rock*, besides just saying that all rocks are hard? The simplest way to define rock is that it is a natural substance which contains one or more minerals held together.

magma – molten rock beneath the Earth's crust

igneous – class of rock formed from cooling magma or molten rock

sedimentary – class of rock formed by particles of material deposited in layers

metamorphic – class of rock formed when other rocks have been changed by heat or pressure

All rocks can be divided into three main classes, based on the method by which they were formed. The original rocks are formed of cooled **magma**, creating the solid bases of the tectonic plates on which we ride. These rocks are called **igneous**, from the Latin word *ignis*, which means fire. And, indeed, igneous rocks are formed through fire – from volcanism, intrusions of magma moving toward the surface, anywhere in which molten rock is cooled to solid form. The second class of rocks are **sedimentary**. These rocks are formed when other rocks are worn down into bits by the forces of erosion and these sediments are deposited to form new rock layers. The third class of rocks are those formed when other rocks are changed by heat or pressure into rocks with different characteristics than the originals. This class of rock is **metamorphic** .

In most areas of Alberta you can find examples of all three classes of rocks. In the next investigation you will begin to examine the characteristics by which scientists classify rocks into the particular classes.

Investigation: General Rock Identification

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Purpose

Examine and describe rock samples with an aim to classify them.

Materials

- hammer/chisel for splitting samples, if needed
- eye protection
- magnifying glass
- vinegar
- water to wash samples, if needed
- 5 or 6 rock samples

Choose samples that have obvious differences. For example, a gravel road or gravel pit, a rocky outcropping, a streambed, or a lakeshore are places which will provide a variety of rock types. In winter you should still be able to find good rock samples along gravel roads, in gravel pits, or along any steep outcroppings (stream banks, construction cutaways, and so on) that are free of snow cover.

Procedure

Step 1: Locate five or six different rocks.

Step 2: Wash the rock samples carefully.

Step 3: Examine each rock sample using the magnifying glass.

Step 4: Try splitting each rock sample. Note if the rock splits along obvious layers. Wear your safety glasses as rock chips may fly up in the air when you split the rock.

Step 5: Put a drop or two of vinegar on each rock sample and see if any reaction occurs.

Observations

Make a chart like the one in question 1. Use the following list of questions and facts to help you analyse your rock samples. As you examine each sample according to these points, indicate your observations in the chart.

A rock is composed of particles or crystals. Describe the particles.

- Are the individual particles easily seen? (yes/no)
- What sizes are the particles? The rock samples may fall into one of the following types according to the particle size.

Fine-grained	Medium-grained	Course-grained	Very Course-grained
Glassy-looking with dot-sized particles and no grain visible.	Particles about 1 mm in size.	Particles about 2 mm in size.	Small pebbles 0.5 cm to 1 cm in diameter.

- When the rock has been broken, look at the surface along the break. A glassy finish or lack of grain suggests a rapidly cooled igneous, or a sedimentary formed out of silt or clay. Generally, a smooth surface with fine grain suggests sedimentary. A rough surface with medium to coarse grains (with sharp-edged crystals) suggests igneous.
- How are the particles put together? Consider the next four bullets to answer this question.
- Are they tight interlocking crystals? (This suggests igneous.)
- Are they individual sand or clay-like particles pressed together? (This suggests sedimentary.)

- Are the particles organized into layers? (This suggests sedimentary or metamorphic.)
- Are the particles cemented together by a substance? (This suggests sedimentary.)
- Is the rock a carbonate? Is there a fizzing reaction when the rock comes in contact with an acid like vinegar? (This suggests sedimentary.)
- When dampened, does the rock smell like mud? (Smelling muddy suggests sedimentary.)
- Does the rock contain animal or plant markings such as shell remnants, leaf prints, and so on? (These suggest sedimentary.)
- What colour(s) are the particles? Colour suggests certain minerals are present in the sample. Combine colour with the other traits to classify the sample. For example, chalk (a sedimentary rock) is white, basalt lava (an igneous rock) is black, while a mix of pink, white, grey, and black crystals suggest granite, one of the most common igneous rocks.

1. Make and complete a chart like the following.

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Individual Particles Seen (yes/no)					
Particle Size					
Surface (rough or smooth)					
How Are Particles Put Together?					
Reaction with Vinegar (fizz/no fizz)					
Smells Like Mud When Wet (yes/no)					
Contains Plant or Animal Markings (yes/no)					
Colour of Particles					

Analysis and Interpretation

2. Based on the traits your samples possess, tentatively classify each of your samples as igneous, metamorphic, or sedimentary. For each sample, explain what made you decide on that classification.

Check your answers by turning to the Appendix, Section 1: Activity 1.

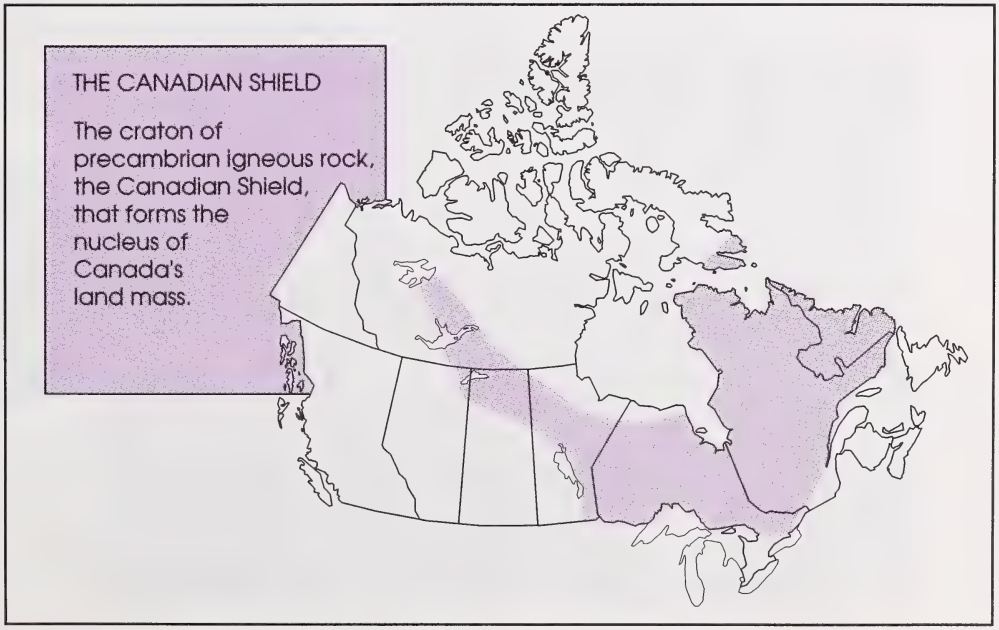
As you discovered in the previous investigation, classifying a rock as belonging to a particular class is a difficult process. You made tentative classifications, but you need much more information about rock composition and creation in order to be more definite. The major process outlining the erosion and forming of rocks is shown in the rock cycle.

VISIONS

Read pages 53 and 54 of *Visions 2*. Picture the rock cycle as it is described and note the formation process of each class of rock.

Igneous Rocks

Your study of plate tectonics in Module 1 showed how the shifting plates lead to solid rock being forced downwards at the edge of the plates becoming molten rock through heat and pressure. At rifts and cracks, magma moves toward the Earth's surface and cools to form solid rock. Tectonic forces also cause uplifts and folding of rock to high altitudes. Volcanoes also bring magma to the surface to cool and form solid rock. These activities form the basis of the rock cycle – the formation of igneous rocks that are the basis of our continents.


THE CANADIAN SHIELD
The craton of precambrian igneous rock, the Canadian Shield, that forms the nucleus of Canada's land mass.

As magma cools to form igneous rock, crystals are usually formed. Rapid cooling leads to small crystals, or none at all. Sometimes cooling is so rapid that bubbles of gas are trapped in the rock. Slow cooling allows much larger crystals of minerals to form.

VISIONS

3. As described in your textbook on page 53, what are the two main types of igneous rock and how is each formed?

4. a. What type of crystal formation occurs in intrusive igneous rocks?

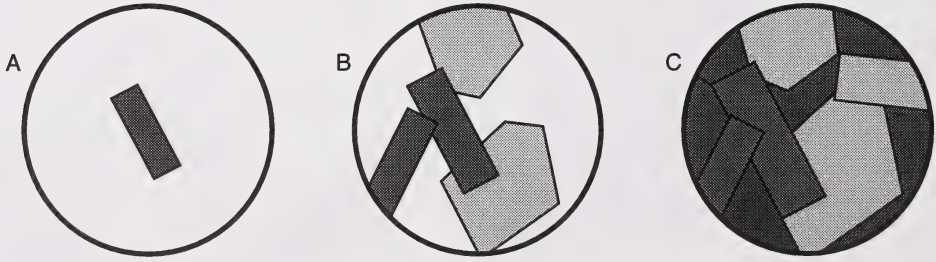
   b. What type of crystal formation occurs in extrusive igneous rocks?

Check your answers by turning to the Appendix, Section 1: Activity 1.

Rapid cooling of magma, as when it breaks through the Earth's crust to reach the ocean floor or is expelled from a volcano, creates extrusive igneous rocks with very fine grain, or no grain at all. Basalt accounts for more than 90% of all extrusive rock. It is a dark, fine-grained rock formed in large part by the melting of the Earth's crust and makes up most of the new rock formed in the ocean ridges.

Another common volcanic rock is obsidian, which has cooled so quickly that it has no observable crystals, but has a black, glass-like look. Scoria is a porous rock formed when lava cools quickly enough to trap many gas bubbles. Froth floating on the top of lava flows hardens to form a rock called pumice. Pumice is so light and porous that it can float on water. The stone used to scrub the dead skin off the bottom of your feet is an example of pumice.

Intrusive igneous rocks are formed when magma forces its way toward the Earth's surface, but is stopped before it breaks through. This allows the magma pools to cool slowly, allowing the growth of large mineral crystals in the rock. These crystals interlock and cement together as they grow as shown in the following diagrams.



The most common intrusive igneous rock, forming the basis of the continental crusts, is granite. It has large, coarse, overlapping crystals of white quartz, pink feldspar, and black mica. Gabbro is another very coarse-grained rock that contains some feldspar, but is considerably darker than granite. Other intrusive rocks are diorites and peridotites, both fairly dark. Of course, rock samples may sometimes have a mix of types like a granity gabbro, depending on the minerals present at formation.

Since igneous rock is formed of hard crystals, what valuable materials do you think are formed as part of some intrusions? Many gemstones are created as particular crystals form in volcanic pipes or other intrusions. One of the most valuable is diamond. To this point the main diamond producer has been South Africa, mining from the famed Kimberley pipe. Much has been in the news in the last while about major companies staking diamond claims in many parts of Alberta. You might want to research what evidence there is to suggest it might be worthwhile exploring for diamonds in this province. What geologic formations might hold diamonds here? Other gems found in igneous material are peridot and zircon. Of course, many gems and metals are found in streambeds or other sedimentary deposits when the original sources are eroded.

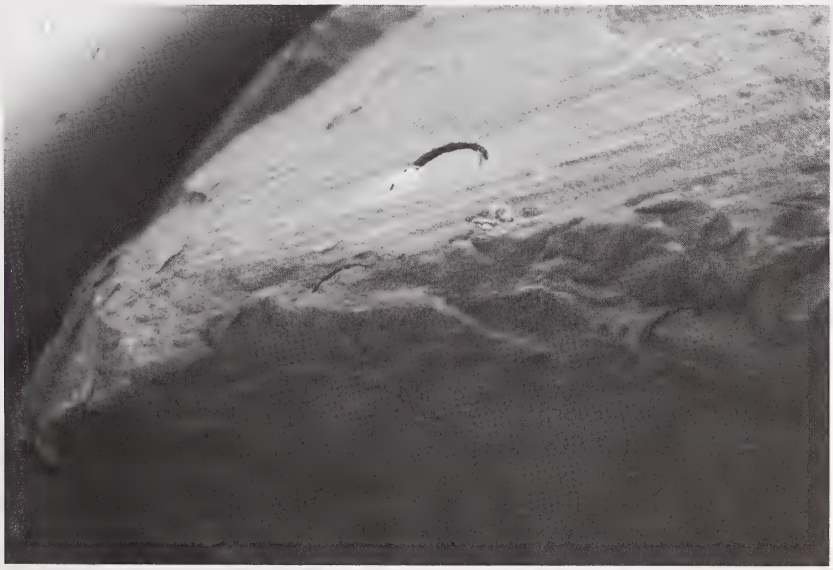
Sedimentary Rocks

When weathering breaks up surface rocks, winds and rivers carry away the broken pieces. Most settle at the inlets to freshwater lakes or on seabeds at the edges of continents. Heavy pebbles settle first, sand further out, and light, fine particles of silt and clay further still. How are these deposits then transformed into solid rock? As layer upon layer of sediment is deposited, pressure begins to compact the lower layers, forcing out the spaces between the grains of the sediment and creating a solid rock. In other cases the spaces between particles are filled by percolating dissolved minerals, effectively cementing the particles together to form solid rock. Rocks formed by this **lithification** process are called **clastic sedimentary**, and include conglomerates (consisting of particles of a wide range of sizes and looking almost like pieces of concrete), sandstones, and shales (formed of silts and clays). Shale is made up of particles which are less than 0.074 mm size. Sandstone is made up of particles ranging from $\frac{1}{16}$ mm to 2 mm in size. Conglomerate has fragments greater than 2 mm in size.

lithification – process by which particles are cemented together

clastic sedimentary – sedimentary rocks that are formed by minerals being deposited into the spaces between the rock particles, cementing these particles together

The following photograph shows an example of a sandstone. Note the fine grain. The arc in the centre is a trace fossil left by a dissolving shell. You will study fossils later in this section.



COURTESY OF GEORGE MUDRYK

organic sedimentary – a rock formed from the remains of living organisms

Another large grouping is **organic sedimentary** rock. These rocks are formed of the remains of living organisms. Swamp plants collected and were compressed to form coal. The shells of shallow-water animals collect to form chalk and limestones. The photograph that follows shows a limestone mountain at Exshaw, Alberta.

COURTESY OF RON MONROE

Other sedimentary rocks are formed through the process of evaporation. Layers of salt may be deposited at the edges of seas as they dry up. Water percolating through rock layers may dissolve a mixture of minerals which may be deposited between particles in rock layers, in veins or cracks in rocks, or as formations like stalactites in underground caves. These rocks that are formed when chemical compounds in water solution precipitate out to form crystal layers or formations are called **chemical sedimentary** rocks.

chemical sedimentary – a rock type formed from the precipitate of a chemical solution

pegmatite – a coarse variety of granite

What gems do you think are created through sedimentary processes? Many are found in **pegmatite** veins in igneous formations. Emerald, aquamarine, topaz, and tourmaline are some of the gems formed from deposits from watery silicate fluids. Mechanical weathering and leaching creates deposits of such metals as gold, copper, iron, bauxite, and so on.

Metamorphic Rocks

As you read in your textbook, there is a third class of rocks, created by heat and pressure, called metamorphic rocks. Metamorphic means changed. Many rocks have experienced conditions of pressure and temperature different from those in which they were first formed, and this has led to the formations of new minerals, new rock textures, and even completely new rocks with no trace of the original. Any previously existing rock may be affected – sedimentary, igneous, or even previously metamorphosed rocks. Many metamorphic rocks show foliation – in which the rock minerals are flattened and aligned to form layers or bands that are easily cleaved.

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Hornfels are fine-grained, dark, flinty rocks with randomly arranged minerals formed by the action of heat on mudstones or basalt. Slate is a fine-grained, often grey tending to blackish-grey rock, in which the mica and other minerals from the original are aligned by pressure to form foliated layers that are easily cleaved. Slate is easily cleaved into flat surfaces, making it ideal for fireplace hearths and mantels and paving stones. Another important building stone is marble. Limestones, if they are almost pure calcium carbonate, recrystallize under pressure and temperature to form white, sugary-looking marble. Impurities add traces of other colours. The wall around the fireplace in the photograph is made of slate, and the large, smooth blocks of stone in front of the hearth are probably marble. Schist is a strongly foliated rock with medium-coarse grain formed from slate or basalt. Frequently, schist is formed primarily of mica, quartz, and inclusions of garnet. Another very common metamorphic rock is gneiss. Gneiss is a coarse-grained, roughly banded rock, often having alternating streaks of dark- and light-coloured materials. Gneiss is formed from granites undergoing severe metamorphism.

Metamorphism, through heat and pressure, causes some minerals to change their crystal structures to form some of civilization's favourite gemstones. Rubies, sapphires, lapis-lazuli, and emeralds and aquamarines in metamorphosed limestone are metamorphic gems.

Investigation: Identifying Three Rock Samples

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☑ F. Evaluating

Follow the directions of this investigation carefully. Pay special attention to the required components and applied science skills.

Purpose

Examine and describe various rock photographs.

Materials

- photographs of rock samples from your science kit

Procedure

Step 1: Take the three black and white photographs from your science kit. The photographs are labeled Rock Sample, Photo 1, Rock Sample, Photo 2, and Rock Sample, Photo 3.

Step 2: Examine each of the rock photographs and describe as many features as you can to help you to classify each rock as either igneous, sedimentary, or metamorphic.

Step 3: Make a chart in which you list the characteristics in a column on the left and the sample numbers across the top. Include the following characteristics:

- general appearance
- organic compositon
- foliation
- crystal/grain structure
- layering

Observations

5. Describe the characteristics of the three rock samples. For example, describe the general appearance (overall look, colour, and so on), crystal or grain structure, whether it is organic or not, layering, foliation, and so on. For each sample, enter a description of the characteristics in your chart.

Analysis and Interpretation

6. How do the grains or crystal structures differ among the samples in the three photographs?

7. Describe the differences in layering between the samples in the photographs.

8. Identify each sample as to its main rock class.

9. What would you say is the most striking characteristic of each sample that really helps identify it?

10. If any of these rocks were to have spaces between the particles, which would you predict to be most likely and why?

Check your answers by turning to the Appendix, Section 1: Activity 1.

11. Now that you have learned more about the various types of rock in existence (especially their characteristics), go back to your first investigation and look at your samples again. Were your tentative classifications correct? Do you need to reclassify some samples now that you have further information? Which ones? Explain which qualities made you reconsider the classification.

Check your answers by turning to the Appendix, Section 1: Activity 1.

The Rock Cycle

Examine the rock cycle shown in Plate 2.2 on page P-4 of *Visions 2* closely. All of the rocks you have ever seen are part of a continuous cycle. Rocks may be formed from sediments, saturated solutions, or magma, and rocks may eventually be turned back into sediments, saturated solution, or magma. This excellent example of the Earth recycling itself is known as the rock cycle. There are many processes involved in changing one type of rock to another.

12. Plate 2.2 in *Visions 2* shows the five materials resulting from the four main processes involved in the complete rock cycle. A full cycle is usually considered starting with liquid magma, being transformed into each type of rock, and returning to magma. List the five materials and the four processes.

13. Shortcuts occur when one stage gets recycled part way through the cycle. Identify one of the these shortcuts and explain how it is a shortcut.

14. One mechanism involved in driving the cycle of rock formation and destruction is plate tectonics. Explain its role.

15. Study Figure 2.3 on page 55 of your textbook. How does the concept of isostasy explain the continuation of the rock cycle?

Check your answers by turning to the Appendix, Section 1: Activity 1.

In this activity you have looked at the basic types of rocks that make up the Earth's crust. In the next activity you will discover how fossils are formed.

Activity 2: Fossils – The Story of Ancient Life

You have read about, seen, and maybe examined shells embedded in layers of rock. You probably have seen or handled pieces of coal. You have used chalk. You may have visited museums and seen dinosaur bones. What do all these things have in common? They are all remains or direct evidence of organisms that were alive in the past. Any preserved evidence of past animal or plant life that lived in prehistoric time before the modern epoch began may be classified as a fossil.

VISIONS

Think of the things you have seen which indicated that something living was once there. Shells, leaf remains, bones, teeth, and petrified wood may all be fossils. Read from the top of page 56 to the middle of page 58 in your textbook to find out how fossils form, how you can classify them, and where they are most commonly found.

THE ROYAL TYRELL MUSEUM/ALBERTA COMMUNITY DEVELOPMENT

The processes of petrification and carbonization are very special methods of preserving the actual remains of the life-form. Situations must be just right for such preservation to occur. The original life-form must be removed from the effects of oxygen – which would lead to decay. In most cases, petrification and carbonization occurred when the organism was rapidly covered by sediment or by being submerged in slow-moving water that contained very little oxygen (such as a swamp). In petrification dissolved minerals moving through the sediments or rocks containing the specimen gradually replace the cells of the original with the mineral. This can create beautiful fossils like opalized petrified wood. Carbonization preserves the carbon-based cells of plants, and sometimes animals. Softer flesh and internal organs of larger animals easily disintegrate, as do soft-bodied organisms like worms, insects, and so on. The carbon "soup" circulating in a layer of carbon material surrounds the organisms' remains and covers them with a thin carbon layer. This layer at least leaves a print of the organism in the surrounding material. The important details which are preserved by these two processes are especially important in reconstructing the structure of the organism.

If you think about all the things that can happen to organisms after they die, it is quite amazing that fossils are as common as they are.

1. Based on what you have read, which of the following objects would be fossils? Explain the type of fossil it represents.

   a. a snail shell found embedded in one-million-year-old sediments that matches a group of snails living today

   b. tracks in sandstone made by an organism that lived 600 million years ago

   c. a tree stump in the logged forest north of Athabasca

   d. a human skeleton found in a peat deposit dated at 5000 years before present

   e. a rock that has all the ridges and markings of a clam shell

   f. the Okotoks glacial erratic shown on page 87 of *Visions 2*

VISIONS

2. What conditions do you think would be necessary for preservation to be successful? Why?

Check your answers by turning to the Appendix, Section 1: Activity 2.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☑ F. Evaluating

Investigation: Making Your Own Simulated Fossils

Follow the directions of this investigation carefully. Pay special attention to the required components and applied science skills.

Purpose

Simulate how some fossils form.

Materials

- plaster of Paris (available in most stores)
- petroleum jelly (Vaseline)
- disposable pie plate or styrofoam dinner plate
- container for mixing plaster
- materials for making imprints (shells, bones, teeth, nuts, crab claws, small irregular rocks, bolts or screws, and so on)
- hand lens

Procedure

Step 1: Coat each of the items you have chosen with a layer of petroleum jelly and place them on a dish.

Step 2: Mix some of the plaster of Paris with water. Follow the directions on the package of plaster until you have a very thick mixture. Pour enough plaster into the plate to form a thick layer.

Step 3: Arrange the items on the wet plaster. Carefully push them into the plaster until they are half covered.

Step 4: Let the plaster dry overnight; then carefully remove the items leaving the depressions they formed.

Step 5: Examine the impressions.

Step 6: Coat the entire surface of the plaster including the depressions with a complete thin layer of petroleum jelly.

Step 7: Make a new mixture of plaster and pour it over the surface in the pie plate. Make sure you fill all the depressions.

Step 8: Allow this plaster to really harden. It may take a couple of days.

Step 9: Remove the plaster from the pie plate and carefully separate the two layers, trying to keep each whole.

Step 10: Examine the fossils with your hand lens.

Observations

3. a. Describe what your first-layer fossils look like in comparison to the original organisms or objects.

   b. Describe what your second-layer fossils look like in comparison to the original organisms or objects.

Analysis and Interpretation

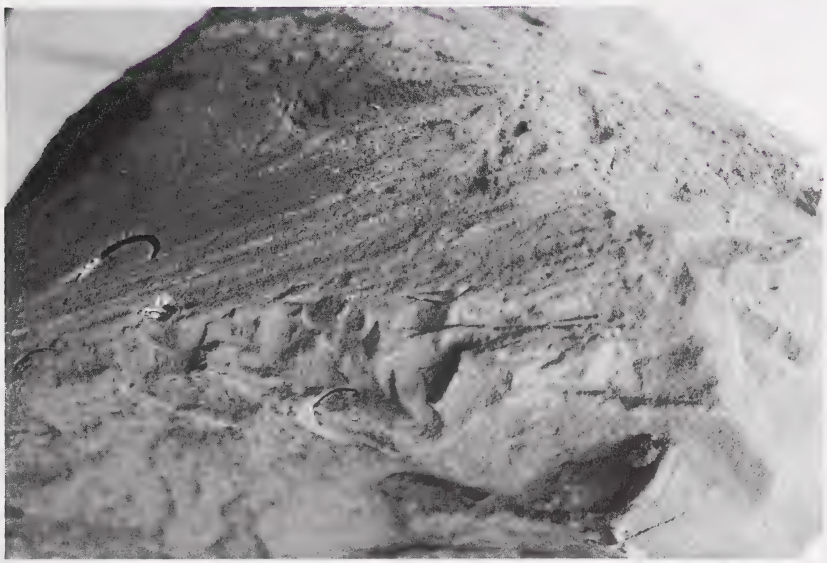
4. What type of fossil did you make first?

5. a. What type of fossil was formed by the second plaster layer?

   b. How are the two types different in appearance?

6. How does this procedure compare with how fossils form normally?

Check your answers by turning to the Appendix, Section 1: Activity 2.



COURTESY OF GEORGE MUDRYK

The fourth type of fossil is the trace, track, trail, or burrow left by an organism. Most often this type of fossil began as the record of some activity in mud or sand. Then drying and lithification turned the material into solid rock. The small structure in the lower right corner of the previous photograph is a burrow of some organism made from the grains of sand. The actual sand grains are about 0.5 mm to 1.0 mm in diameter and are cemented together. Also notice the impression on the left side left by a shell that has disintegrated and fallen out. This fossil was found at a road construction site about 80 km northeast of Edmonton. Such burrows and traces might tell the size and weight of the organism. Tracks might tell you how it walked or moved, whether it had toenails (which might explain much about what group of animals it is related to), whether the animal travelled in herds, and so on.

7. From what you have read so far, why is it that most fossils are found in sedimentary rock?

Check your answers by turning to the Appendix, Section 1: Activity 2.

Only a few organisms that have lived in Earth's history have been preserved as fossils, and many that were preserved in older rocks have since been eroded and destroyed. Yet this incomplete record of life is the main tool used by scientists to develop the geological and biological history of the planet.

What information can be interpreted from an identified fossil specimen? It can help to tell you the relative age and the environment of deposition of the rocks the fossil was found in. When determining ages of rock strata, it is often found that some species of organisms only lived during certain times in the Earth's history. These organisms appeared in the rock record at some particular time and later became extinct. Some species existed for only very short periods of time, while others have existed through millions of years.

Activity 3: Principles of Stratigraphy

Remember your trips through the mountains of Jasper, Banff, or Crowsnest Pass? The mountains show massive uplifts of rocks, exhibiting layers of rock shifted to many different angles, with some showing folds and undulations in the strata. Maybe you've been lucky enough to visit the spectacular badlands along the Red Deer River near Drumheller or further southeast in Dinosaur Provincial Park. The Badlands show relatively horizontal rock strata severely eroded to depths of more than 100 m. You can clearly see the different sedimentary rocks laid down millions of years ago. Or is there a place near your home where rock layers are revealed? You have probably wondered about the story of the Earth as revealed by these rock layers in the Rockies and in the Badlands. What is the story that might be revealed by the rocks in your local area?

COURTESY OF GEORGE MUDRYK

Now that you can identify the basic rock types and understand how they are constantly being created and destroyed, your next challenge will be trying to determine how a group of rocks tells you a story. Being a geologist is much like being a detective. You find certain clues and use them to try and reconstruct the Earth's history.

View the video entitled *Sedimentary Rocks*, Magic Lantern Communications, ACCESS Network, to review some of the information you have learned about sedimentary rocks, and to see how geologists use stratigraphy to analyse rock layers and structures to determine the conditions under which the rocks were originally laid down. This video is available from Learning Resources Distributing Centre. Answer the questions that follow. You may find it useful to review the video as you answer the questions.

1. Explain the difference between mechanical and chemical weathering.

2. a. What is clastic sediment?

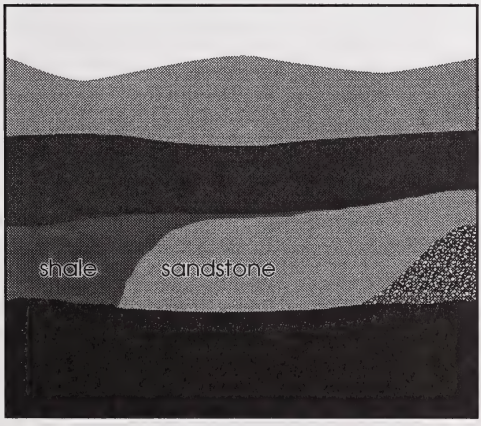
   b. What are the four main types of clastic sediment?

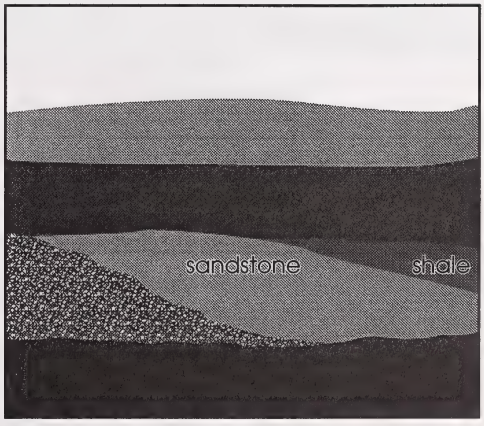
3. What are the three ways in which sediment is moved and deposited in another location?

4. a. Natural sorting of sediment occurs as wind or water is slowed enough so it deposits the material it is carrying or moving. List these four materials in order from the one that would be deposited first to the one carried the furthest.

   • silt • clay • pebbles • sand

   b. The sorting of deposits can give information about the location of an ancient lake or ocean shore, the direction of current or stream flow, and the strength of the current. Look at each diagram. Indicate the direction of stream flow in each diagram as being left-to-right or right-to-left. Which shows the strongest current?





5. What two processes of lithification make solid sedimentary rocks?

6. Explain the process of limestone creation.

7. What are three areas where deposition from water occurs?

8. In geologic terms, explain the sentence, "The present is the key to the past."

9. a. What is the principle of original horizontality?

   b. Most deposition occurs according to this principle. What types of deposition vary from this?

10. a. What is crossbedding?

    b. What information can be revealed in crossbedded strata?

11. a. What information can be revealed by ripple marks?

    b. Draw a ripple mark that would show that the movement of water was from left to right.

12. a. Where would preserved mud cracks have been formed?

    b. What types of information can they reveal?

13. What are the traits mentioned that suggest a column of rock strata was formed in a freshwater lake?

14. How do lake deposits differ from river deposits?

15. a. What are five resources which come from sedimentary rocks or uses of sedimentary rocks today?

    b. How many of these resources or uses can you find in your area?

Check your answers by turning to the Appendix, Section 1: Activity 3.

stratigraphy – the study of rock strata and their sequence or order

When scientists try to piece together the clues to the puzzle of the Earth's history, they work mainly with the layered rocks visible on the surface and from cores from drilling samples. The layers generally formed one after another in sequence. The study of these strata and their sequence is the basis of **stratigraphy**. The principles or laws governing stratigraphy are generally empirical and were developed mainly through observation. These principles help guide scientists in their interpretation of rock strata sequences.

In the late 1700s, James Hutton, a Scottish naturalist, suggested that the processes that people observed going on at the current time are the same processes that created all the rock strata in the past. The processes may not always have acted for the same length of time or with the same intensity, but these processes eroded, deposited, and created rock layers in essentially the same ways throughout the Earth's existence. This idea is known as the **principle of uniformitarianism**, often stated simply as "The present is the key to the past."

The greatest amount of sedimentary rock seen today was deposited in oceans. As a new layer was laid down, it tended to be horizontally placed over the previously laid material. This is known as the **principle of original horizontality**. Consequently, if beds appear to be folded or tilted, then some geologic event has caused the beds to be altered from their original horizontal state.

When you look at an outcrop, you probably already consider the layer on the bottom to be older than the layer on the top. This is the **principle of superposition**. It states that in a sequence of undisturbed sedimentary rock, the layers become younger as you go from the bottom to the top. Figure 2.1 shows a sedimentary sequence with six layers. Study the sequence and answer the questions that follow.

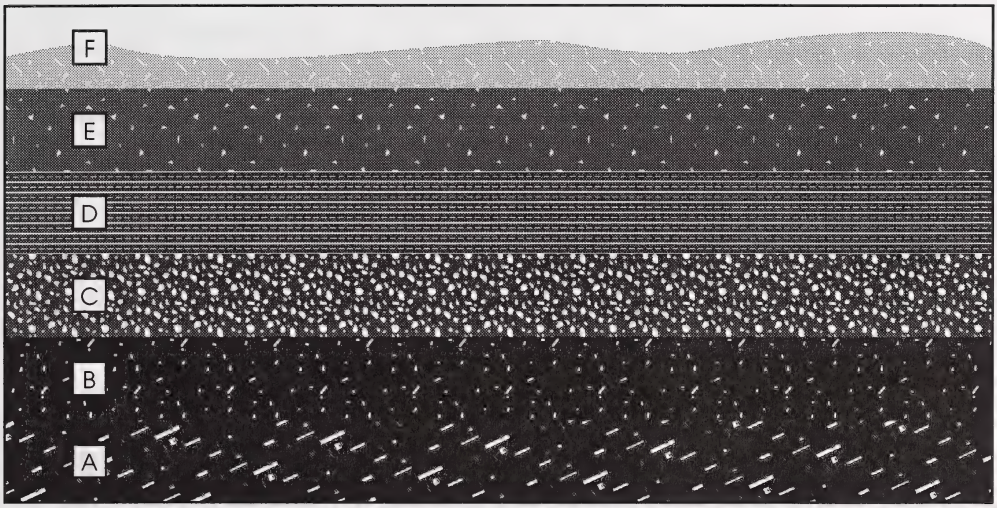


FIGURE 2.1 Sedimentary Sequence

16. a. Which is the oldest rock layer in the diagram?

    b. Which is the youngest rock layer?

    c. Which layer was deposited first? Which one last?

    d. Name the layers younger than layer C.

Check your answers by turning to the Appendix, Section 1: Activity 3.

Another principle used in unravelling the clues in a series of strata is the **principle of cross-cutting relationships**. This principle states that a disrupted pattern has to be older than the event that disrupted it. The disruptions are often caused by the intrusion of igneous rocks, fracturing the existing layers, or faults occurring across rock layers. The diagrams here show some examples. In Figure 2.2 intrusion E is younger than layers A, B, C, or D. In Figure 2.3 the fault is younger than the layers it cuts through.

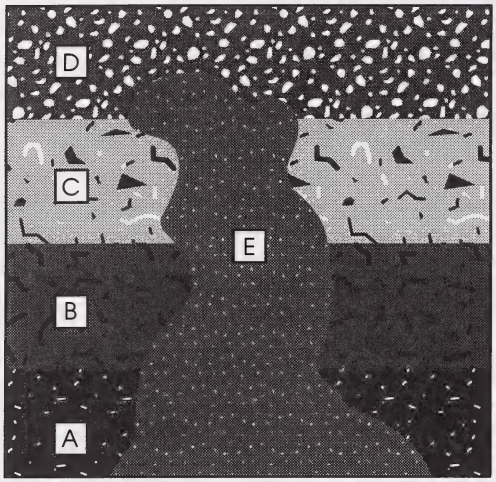


FIGURE 2.2 Intrusion

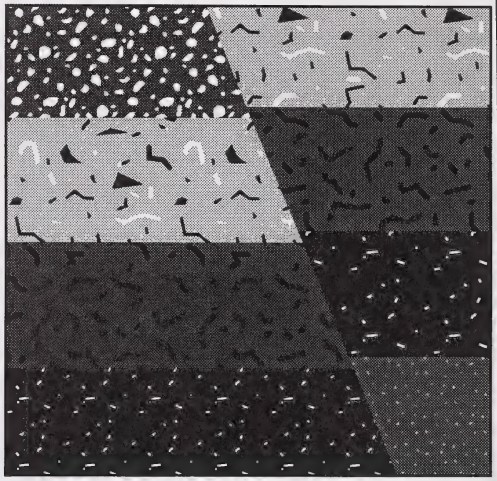


FIGURE 2.3 Fault

unconformity – some type of change that has occurred between older rock and younger rock

Within any sequence of rock, there may not be a complete history. If the land is uplifted so it is no longer under water, most deposition no longer occurs; thus, no new rock layers are added to the sequence during that period. If folding or uplift have occurred sometime in the past, some of the layers may have been removed by erosion. When it appears that this has happened, the boundary between the eroded rock and the younger material on top is known as an **unconformity**. Look at Figure 2.7 on page 64 of *Visions 2* to see how an unconformity may occur.

VISIONS

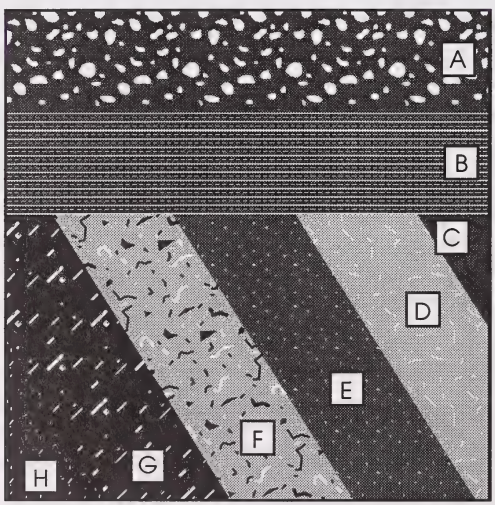


FIGURE 2.4 Tilted Sedimentary Layers

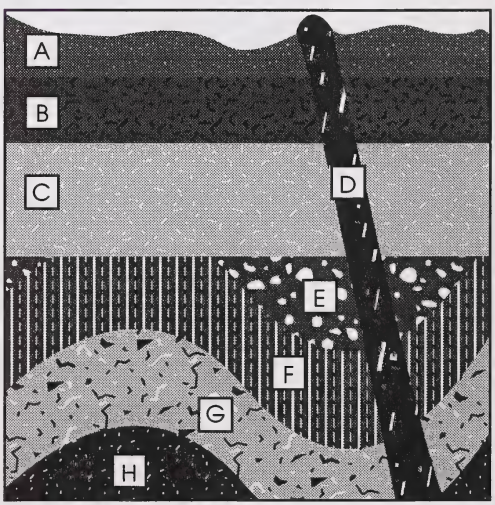


FIGURE 2.5 Unconformity and Intrusion

17. a. Now you have an understanding of some of the tools needed to develop a geologic history of a rock sequence. Indicate the age sequence of the rocks in Figure 2.4 and Figure 2.5 by arranging the label of each layer from oldest to youngest.

    b. What stratigraphic principles did you apply to the sequence in Figure 2.4 to help you decide the relative ages?

    c. What stratigraphic principles did you apply to the sequence in Figure 2.5 to help you decide the relative ages?

Check your answers by turning to the Appendix, Section 1: Activity 3.

VISIONS

As geologists developed a better understanding of how rock sequences could be interpreted using stratigraphic principles, paleontologists found that fossils also appeared to follow certain principles. Read about William Smith and his work on pages 61 to 64 of *Visions* 2. You should realize that it was only through careful observation and detailed notes that Smith was able to recognize the similarities in both the rock and fossil sequences in his part of England. He constructed complete stratigraphic sequences, also called **stratigraphic columns**, for each of the outcrops he studied. He was then able to correlate the columns, concluding that those sequences with similar rock units and fossil content, even though in different locations, were the same age. His work led to the acceptance of the **principle of faunal succession** which has resulted in worldwide correlation of rock units.

stratigraphic columns – complete sequences of rock layers for a particular rock outcropping

18. a. What are zone or index fossils?

    b. How do they help scientists correlate rock strata?

Check your answers by turning to the Appendix, Section 1: Activity 3.

Geologists identify rock strata by such properties as grain size, mineral composition, and colour. Fossils common among rock strata also help in correlating distant formations. Other clues also help correlate strata around the globe. Intense volcanic eruptions spread thin layers of volcanic ash on all the Earth's surface. Sediments deposited at the same time also are aligned magnetically according to the position of the Earth's magnetic poles at that time.

Look at Figure 2.6. Although rock layers may be of different thicknesses and may be missing some layers in the sequence, correlations can be made based on rock type and fossils present in the layers.

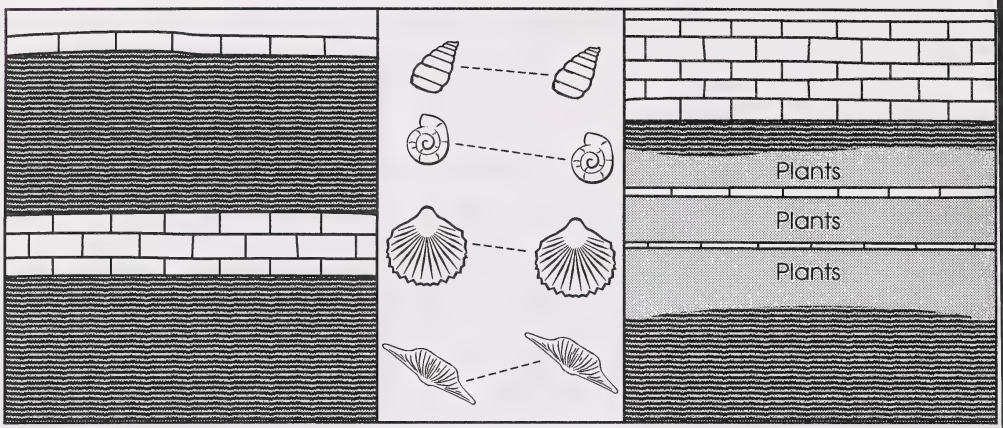


FIGURE 2.6 Rock Strata and Fossil Correlation

19. How was Smith's work very important in forming the basis of piecing the fossil record together and developing complete stratigraphic records?

Check your answers by turning to the Appendix, Section 1: Activity 3.

VISIONS

Looking again at the information on page 63 of your textbook, you can make some simple correlations. Each sequence listed on page 63 can be drawn side-by-side in order to see how they are spatially oriented. In Figure 2.7 the layers are drawn side-by-side. Use this illustration to answer questions 20 and 21.

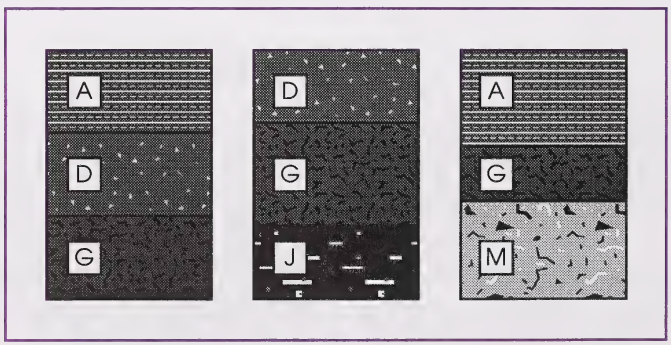


FIGURE 2.7 Stratigraphic Correlation

20. a. In the illustration show the correlation among these rock units by drawing the three columns and using dotted lines to connect the correlating layers.

    b. Draw a fourth column in which all layers are combined in proper order to show a complete geologic column.

21. a. What do you think happened to the missing layers in these sequences?

    b. What geologic term names this situation?

VISIONS

22. a. Interpret the stratigraphic sequence presented in Figure 2.8 on page 65 of *Visions* 2. Examine each layer and describe some of the conditions that existed at the time based on the description of each layer given in the textbook.

    b. Examine the hypothetical sequence in terms of the questions in the textbook. Do questions 1, 3, 4, 5, 6, 7, 8, and 9 on pages 65 and 66 of *Visions* 2.

Check your answers by turning to the Appendix, Section 1: Activity 3.

You will do more work with stratigraphic principles in the next activity when you study how they help scientists make determinations about the complete geological history of the Earth.

Activity 4: The Geologic Time Scale

From the previous activities you learned how to correlate sequences of rock based on the type of rocks and fossils found in the strata. Using this technique with information from many regions, scientists pieced together the geologic time scale. This was a totally **relative** time scale in the beginning, with well described sections of rocks and fossils being representative of a certain time interval. Some absolute dates have been added which indicates the immense span of time over which geologic processes have been operating.

VISIONS

Read the section Geological and Absolute Time on page 41 and 42 of *Visions* 2. Then answer the following questions.

1. What geologic events might you measure using a small time scale?

2. What is generally accepted as the age of the Earth?

Check your answers by turning to the Appendix, Section 1: Activity 4.

Since geologic time is so immense and sometimes difficult to comprehend, a model which allows you to place events and organisms in their proper place can be very helpful.

Science Skills

- ☑ A. Initiating
- ☐ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☐ E. Synthesizing
- ☑ F. Evaluating

Investigation: A Model of Geologic Time

Follow the directions of this investigation carefully. Pay special attention to the required components and applied science skills.

Purpose

Construct a model of geologic time including major physical and biological events of Earth's history.

Materials

- *Visions 2*
- material to create a scale of some kind (such as a calendar, computer paper, and so on)
- coloured pencils

Procedure

You will do Activity 2.1 on pages 42 and 43 of *Visions 2*. Read all the instructions in the textbook carefully before beginning. Although the directions are written to a group, individuals can complete all the steps successfully. The steps are simplified as follows:

Step 1: Choose a medium in which to present your geological timeline.

Step 2: Develop a practical scale for your timeline. This is a very important step in developing a meaningful timeline. Remember the intervals of time must be the same from beginning to end.

Step 3: Set up the blank time scale on your medium.

Step 4: Plot the major events from Table E.3 on pages 554 to 556 of *Visions 2*.

Observations

You now have a model of the Earth's historical record. If you used a calendar, you should have very few events from January to the middle of December. After December 15, there are more and more events with the last day of December having a large number of events. If you used computer paper, your first four or five pages should be almost blank with most of the events on the last one-half of a page.

Analysis and Interpretation

3. Begin watching the video entitled *Geologic Time* which comes from the *Earth Revealed* series, ACCESS Network. This video is available from Learning Resources Distributing Centre. Watch the portion on the Earth's geological history and timeline until it begins to discuss James Hutton, at about the four minute mark. Rewind and rewatch if you need to. Compare the events and the timeline presented in the video with the one you developed. Discuss such points as whether you mentioned similar events, whether there were any discrepancies, and whether the scales were similar.

4. Write a short story describing your timeline's events (taking account of its scale and medium, too) as described in the Analysis and Interpretation question on page 43 of *Visions 2*.

Check your answers by turning to the Appendix, Section 1: Activity 4.

Watch the next fifteen or so minutes of the video *Geologic Time* up to the point where it begins discussing absolute dating (Carbon 14 and Uranium 235). This portion gives a very good review of stratigraphic principles.

5. What were the evidences of land buildup that James Hutton recorded?

6. What were the major contributions James Hutton made to geology?

7. What are the stratigraphic principles you have already studied that were reviewed in the video? Briefly describe each principle.

Check your answers by turning to the Appendix, Section 1: Activity 4.

periods – portions of time that are based on recognizable crustal changes that occurred in one or more areas

What are some of the time units that scientists use in describing geologic time? You may have seen the movie *Jurassic Park*. The term *Jurassic* refers to one of the **periods** in which dinosaurs lived on Earth. What are other names you may have heard?

VISIONS

Read about how geologists have divided the Geologic Time Scale in the three paragraphs after Activity 2.1 on pages 43 and 44 of *Visions 2*. Coloured Plate 2.1 gives a useful visual representation of the units of geological time and their relationships and dates. Then answer the questions that follow.

8. What is the largest unit on the Earth's time scale and how many are there?

9. How have geologists determined the boundaries of these units?

10. What is the difference between periods and epochs?

11. Why are the more recent parts of the time scale divided into smaller time intervals?

Check your answers by turning to the Appendix, Section 1: Activity 4.

Your study of stratigraphy showed you how rock layers could be read to give you the relative ages of the rock layers (this layer of sandstone is above this layer of shale, so it is probably the younger layer), and how rock layers around the globe could be correlated by rock type and fossils present in the layers. It is these principles that have helped scientists map rock layers around the Earth to develop the complete history of the Earth's surface, its geological time divisions, and their identifying rock types and fossils in relative terms. You will study more about geological eras, periods, and epochs and their characteristics, especially in Alberta, in Section 2.

Activity 5: Absolute Dating

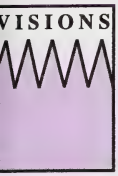
In the early days of the science of geology, geologists started to put rock and fossil deposits worldwide in some type of order. Using comparisons of sequences of rocks, geologists can tell you which are older, younger, and the same age as each other. But what is that age in absolute time? What are they talking about in actual years? Until this century only very general calculations were made. One method was to calculate how long it had taken for all the sediments in sedimentary rocks to be deposited. A second idea was to calculate how long it had taken the oceans to become as salty as they are today, knowing how much salt is brought to the oceans by rivers every year.

1. What would be the variables that would make times calculated by these methods inexact?

Check your answers by turning to the Appendix, Section 1: Activity 5.

Both of these methods had flaws in the underlying assumptions, but they did have positive results in that they made scientists realize that the Earth was millions of years older than previously thought.

The discovery of radioactivity, at the beginning of this century, allowed scientists to develop methods for determining absolute ages of the Earth's rocks and fossils. How does this work? Watch the last part of the video entitled *Geologic Time* about radioactive dating; then read the section entitled Radioactive Elements Help Us Determine Absolute Ages on pages 44 and 45 of *Visions 2*.



Investigation: Understanding Half-Life

Follow the directions of this investigation carefully. Pay special attention to the required components and applied science skills.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Purpose

Simulate how isotopes decay and are used to measure time.

PATHWAYS

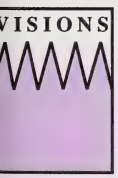
If you are with a group of students, complete Part A. If you are on your own, do Part B.

Part A

Materials

- 200 pennies or small markers (like bingo markers) with one side of each marked
- 100 nickels or larger markers with one side of each marked
- 100 playing dice
- 3 large containers to hold the coins or markers (1 L jars or cans)
- paper bag
- paper and pencil
- graph paper

Procedure



As a group of students, follow the instructions for Activity 2.2 on pages 45 to 48 of your textbook, doing Parts A, B, and C.

Observations

2. Draw a graph based on the number of coins or dice remaining after each toss for Parts A and B. In Part C draw the pattern created by the coins after each toss. Use one colour for nickels and pennies on a section of graph paper. Since there are 100 coins, your pattern should be 10 coins by 10 coins.

Analysis and Interpretation

3. Do questions 1, 2, 3, 4, and 5 on pages 47 to 49 of *Visions* 2. If you did not have the 100 dice, describe your results for the coins (or markers) only. You would also omit textbook question 5.

4. Knowing the half-life of your two-sided pennies (or markers), predict whether or not the six-sided dice would have a longer or shorter half-life.

Check your answers by turning to the Appendix, Section 1: Activity 5.

End of Part A

Part B

Materials

- 100 pennies or small markers (like bingo markers) with one side of each marked
- 100 nickels or larger markers with one side of each marked.

  Note: Markers would also work if they were the same size, but a different colour than the ones representing pennies.
- 100 playing dice, if available, but not necessary for this part
- 3 containers to hold the coins or markers (1 L jars or cans)
- paper and pencil
- graph paper

Procedure

VISIONS

If you are on your own, do Part A and Part C of Activity 2.2 on pages 45 to 48 of *Visions* 2. If you have access to 100 dice, you could also complete Part B. Follow the procedures for each part except for Step 7.

Observations

5. Draw the shape of the pattern created by the coins in each of Parts A and C. Draw the shape of the pattern created by the dice in Part B if you were able to complete it.

Analysis and Interpretation

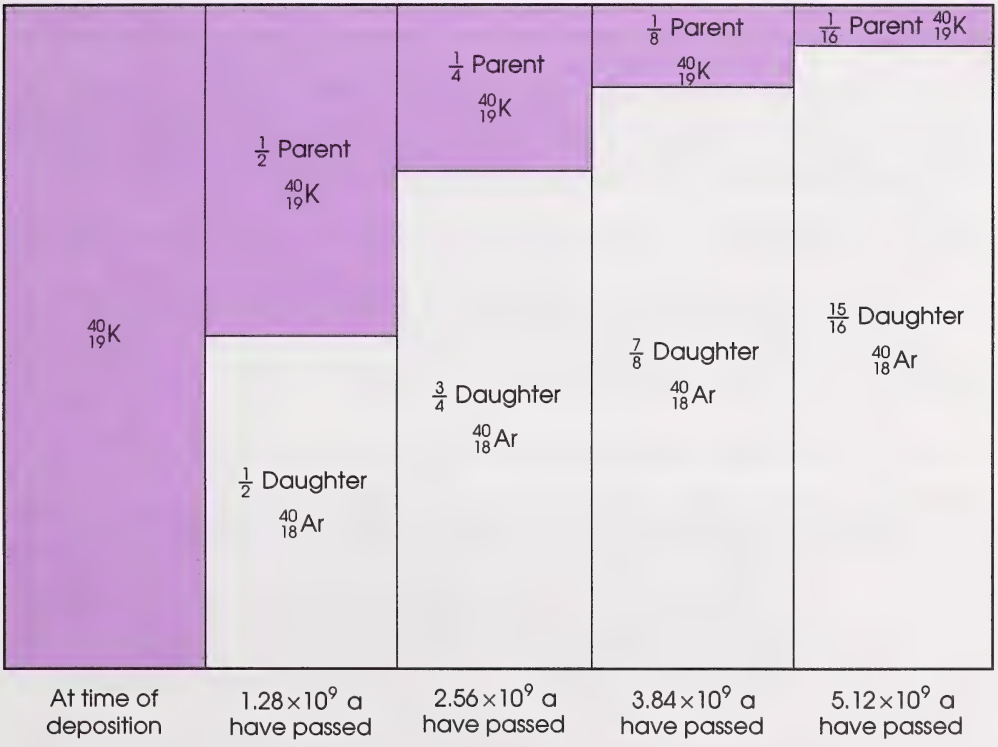
6. Do questions 3 and 4 from the Analysis and Interpretation section in Part A of this investigation.

Check your answers by turning to the Appendix, Section 1: Activity 5.

End of Part B

The following diagram shows the change in relative parent and daughter material as the original material moves through a number of half-lives. Note also the relationship of time to the process.

Radioactive Decay of Potassium-40 ($^{40}_{19}K$) to Argon-40 ($^{40}_{18}Ar$)



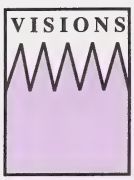
Note: Each bar represents a half-life in the decay of Potassium-40.

Of course, radioactive decay is ongoing and gradual. The previous illustration shows benchmarks at exact half-life steps. Figure 2.2 on page 48 of *Visions* 2 gives a better idea with a decay curve that shows the gradual transformation of parent to daughter material.

7. These questions will allow you to practise calculating half-lives. Use Figure 2.2 and Table 2.1 for information to help you complete questions 1, 3, 5, 7, and 9 on pages 49 and 50 of your textbook.

Check your answers by turning to the Appendix, Section 1: Activity 5.

Radiocarbon Dating



As you can see from Table 2.1 on page 49 of your textbook, all of the radioactive elements listed there have very long half-lives. They are most useful in dating rocks formed in the distant geologic past. Are there any isotopes that are suitable for dating materials a few thousand or even a few hundred years old? Are there isotopes that can be used to date fossils or other objects that were once living? Carbon 14 is an isotope used to date carbon-containing material up to 40 000 years old. Although the textbook suggests it can be used to date material to 70 000 years, dates older than 40 000 years become increasingly less accurate. Read Radiocarbon Dating on pages 51 and 52 of *Visions* 2.

Using what you know about dating techniques, answer the following questions.

8. How much $^{14}_{6}C$ will be found in a piece of charcoal after 28 650 years if it had 24 grams to start with?

9. Will all the $^{14}_{6}C$ eventually disappear?

10. Explain whether or not $^{14}_{6}C$ is useful for dating the basalt in a lava flow?

11. If absolute dating methods are available, why is the geologic time scale with its rock and fossil descriptions still used extensively by scientists?

Check your answers by turning to the Appendix, Section 1: Activity 5.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

The geological history of the Earth is one of constant building up and wearing down of the Earth's surface. Magma (molten rock) cools when it reaches or approaches the Earth's surface to form igneous rocks like granite. The cooling of magma formed igneous cratons, the bases of the continents. Wind and water erode rock and deposit the sediments in layers. Through the process of lithification, pressure and dissolved chemicals compress the deposited particles and cement them together to form sedimentary rock. The main types of sedimentary rocks are sandstone, shale, limestone, and conglomerates. The third type of rock, metamorphic, is formed from other rocks being severely changed by strong heat and pressure. Common types of metamorphic rocks are marble, slate, and gneiss.

Science Skills

- ☑ A. Initiating
- ☐ B. Collecting
- ☑ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

1. Describe the characteristics (grain/crystal, foliation, colour, and other characteristics) for each of the following types of rocks in chart form. In your chart, group the rocks according to their classification (i.e. igneous, sedementary, and so on).

• granite	• marble	• shale	• limestone
• sandstone	• basalt	• gneiss	• conglomerate

Check your answers by turning to the Appendix, Section 1: Extra Help.

Fossils

Fossils are remains or traces of life in the prehistoric past. Petrification (in which the original organism is turned to "stone") and carbonization (in which prints of carbon remain) are the two main processes of fossilization. The four types of fossils are shown in Table 2.1.

TABLE 2.1 THE FOUR TYPES OF FOSSILS

Type of Fossil	Example
Actual Remains	dinosaur bones, petrified wood
Imprint or Mould	hollow imprint of shell or anthropod in rock
Cast	stone-like fossil created when a mollusc in rock dissolves and the cavity is filled with minerals
Trace	some form of trace, track, or burrow such as a dinosaur footprint

2. You have been helping your family put in new sidewalks in your backyard. The cement has just been poured and leveled and you make an imprint of your hand and sign it with your initials and the date. Based on the definitions of *fossil* in this module and your textbook, will this become a fossil? Explain.

Check your answers by turning to the Appendix, Section 1: Extra Help.

Stratigraphy

Stratigraphy is the study of rock strata. A number of underlying principles help scientists determine relative ages and relationships among the rock layers.

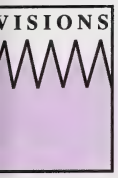
3. Match each definition with the appropriate stratigraphic principle.

_____ a.	The vertical arrangement of fossils occurs in a definite progression around the globe.	i. principle of superposition
_____ b.	New rock layers are created in relatively flat layers over previous layers.	ii. principle of uniformitarianism
_____ c.	Any disrupted rock pattern has to be older than the event that disrupted it.	iii. principle of original horizontality
_____ d.	The geological processes in the past are the same processes at work today.	iv. principle of faunal succession
_____ e.	Rock layers become older as one moves from the surface to deeper strata.	v. principle of cross-cutting relationships

Check your answers by turning to the Appendix, Section 1: Extra Help.

Dating

Scientists date rock layers relative to each other, based on their knowledge of stratigraphic principles and the development of the fossil record. Actual dating methods using radioactive elements has given precise understandings as to the age of rock layers, fossils and other artifacts, and an idea of the immense age of the Earth itself. Carbon 14 $\left({}^{14}_{6}\mathrm{C}\right)$, with its half-life of 5730 years is useful for dating organic materials that lived in fairly recent geological history. Other radioactive elements have longer half-lives, such as Uranium 238 $\left({}^{238}_{92}\mathrm{U}\right)$ that has a half-life of 4.51×10^{9} years, and are used to measure the large ages of ancient rocks, such as those formed at the beginning of the Earth, 4 500 000 000 years ago.



4. Do question 3 on page 53 of *Visions* 2.

5. a. After two half-lives, what percentage of the Uranium 235, the parent material, would remain?

   b. A rock sample is tested and shows that 12.5% of rubidium-87, the parent material, remains. This means that three half-lives have passed. How old is the rock being sampled? (Use the information in Table 2.1 on page 49 of *Visions* 2.)

Check your answers by turning to the Appendix, Section 1: Extra Help.

Enrichment

There are a number of great videos that you can watch if you want to know more about rocks and minerals.

1. If you are interested in the many minerals which form the rocks, the video entitled *Minerals: The Materials of Earth* from the *Earth Revealed* series shows you how the minerals form, how they become part of a rock, and the economic importance of certain minerals. This video is distributed by Magic Lantern Communications Ltd.

2. The video entitled *Volcanism* from the *Earth Revealed* series, distributed by Magic Lantern Communications Ltd. and ACCESS Network, shows spectacular eruptions and describes how the different types of volcanoes are formed.

Check your answers by turning to the Appendix, Section 1: Enrichment.

If you have access to a library, you may wish to use some of the references from the Further Readings on page 79 at the end of Chapter 2 of *Visions 2* to investigate one of the following .

3. Much has been written about the weird and wonderful fossils of the Burgess Shales in Yoho National Park. Read about this unique World Heritage Site and how it has altered many previously held views about life on Earth.

4. Make your own rock or fossil collection from your local area. Try to find as many different types as possible. Classify them and use a rock or fossil guide to identify as many as possible. Two helpful guides are *Simon and Schuster's Guide to Rocks and Minerals* (New York: Fireside Books, 1978) by Mottana, Annibale et al. and *The Audubon Society Field Guide to North American Fossils* (New York: Alfred A. Knopf) by Ida Thompson.

Check your answers by turning to the Appendix, Section 1: Enrichment.

Conclusion

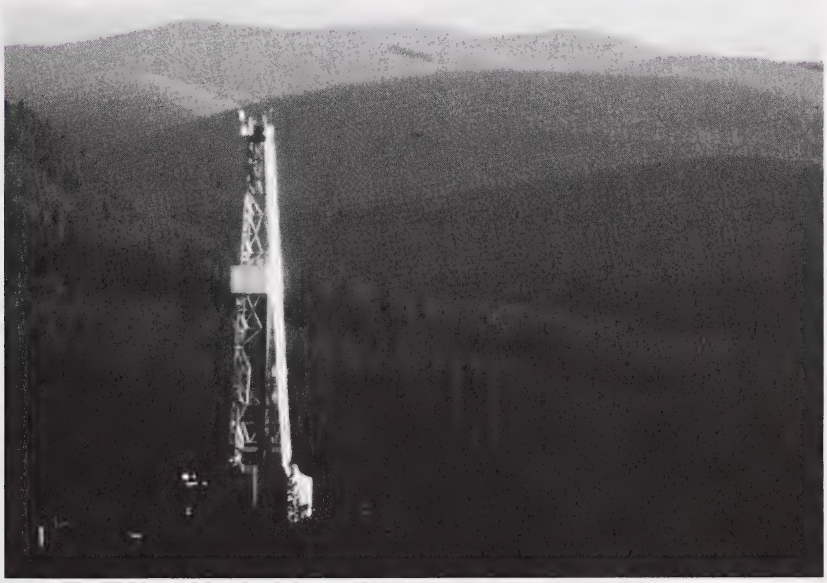
In this section you have found out about the different rock classes (igneous, sedimentary and metamorphic) and how these rocks recycle themselves around the crustal layer of the planet. These rocks tell a story as well – one you can figure out using the principles of stratigraphy. You have learned how the remains of ancient life have left a fossil record in sedimentary rocks. Using the rocks and the fossils together, you have learned how geologists are able to correlate sequences of rocks worldwide and develop relative time sequences. Radioactive dating has given scientists the tools to date rock layers or fossils with actual ages. You now have some of the tools to help you understand the geological history of your home area as well as any other area.

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 1.

Section 2

Ancient Life and Its Importance Today



WESTFILE INC.

Major geological events and processes have given Alberta and its citizens major economic advantages. The massive uplifts and folds of rock strata along the western border have been moulded by glaciation into world known tourist destinations like Jasper, Banff, and Waterton National Parks. The erosion in the badlands along the Red Deer River has unearthed rich fossil beds which have produced many of the world's best dinosaur skeletons. Besides being well-known among the world's paleontologists, the area is also a magnet for tourists, especially since the development of The Royal Tyrrell Museum of Palaeontology in Drumheller, Alberta. But the vast oil and gas reserves deposited in Alberta's geological history have affected the modern face of our province like nothing else. The revenues produced and the people employed in the petroleum industry make it one of Alberta's most important industries.

What is the geological history of Alberta in particular? In this section you will study how paleontologists have interpreted Alberta's stratigraphic column and how they use it to help them in their field research to locate, collect, and display fossils. You will also study the theories on how Alberta's petroleum reserves were deposited and how geologists use their knowledge of rock strata and modern techniques to locate oil and gas reservoirs. It is in these studies where you will see the real-life applications of the material you have been studying so far in this module.

Activity 1: Paleontology – Looking Back

The term *paleontology* was used in the previous section. What is your understanding of the term? Paleontology is the scientific study and interpretation of ancient life-forms and their evolution based upon the fossil record of plants and animals. For example, the study of dinosaur bones can lead to the re-creation of ancient life-forms as shown in the following photograph. This can give much information about the evolution of these and other ancient animals.

THE ROYAL TYRRELL MUSEUM/ALBERTA COMMUNITY DEVELOPMENT

You have studied stratigraphy, analysed specific rock columns, and seen how geologists can correlate rock layers in separate locations according to rock type and fossils present. Geologists have correlated rock layers worldwide, a formidable task considering that the Earth's surface rose and fell so that during particular periods some areas were underwater and receiving layers of deposits while other areas were dry and undergoing erosion with no deposition occurring. But the complete geological column has been developed. Turn to P–3 of *Visions 2* and study Plate 2.1, noting the time divisions and the characteristics of each division shown in the illustrations.

VISIONS

1. Create a chart like the following, and take the information from Plate 2.1 on page P–3 of *Visions 2* and place it into your chart to give yourself a good summary of the standard geologic column. From the illustrations, also indicate the main life-forms and major developments (as shown in the fossil record) for each era. Some information has been filled in for you. You will need to expand the spaces in the chart to fill in the required information.

Era	Period	Epoch	Years Past (in millions)	Life-Forms and Major Events
Cenozoic				
				• splitting of the continents, earthquakes
		Miocene		
			66	
Mesozoic	Cretaceous		144	• extinction of the dinosaur
				• first vertebrates appear
	Silurian			

Check your answers by turning to the Appendix, Section 2: Activity 1.

VISIONS

What are the major traits by which geologists and paleontologists distinguish each era? As you learned in Section 1, eras are determined by major environmental or geological changes. Table E.3 on pages 554 to 556 of *Visions 2* gives you detailed information about each era and period.

The Precambrian Era stretches from the creation of the Earth (4.5 billion years ago) to 570 million years ago. In this era the Earth's crust, continents, and oceans formed. The oldest known rocks formed about 3.8 billion years ago and life appeared 3.5 billion years ago. The oldest fossils of these single-celled organisms have been found in Australia. Bacteria-like organisms and blue-green algae appeared. The presence of algae began a significant change to the Earth's atmosphere which caused conditions to become favourable for more complex life-forms.

The Earth's primitive atmosphere was quite inhospitable to life. As the crust cooled, water vapour could condense to form oceans, but an active hydrologic cycle would be suggested by the heat still present at the Earth's surface. The other main gases were ammonia (NH_3) and methane (CH_4). Unfiltered sunlight broke up these gases, allowing the light hydrogen to escape into space and nitrogen to remain and become a major atmospheric gas. Some oxygen was also contributed to the atmosphere in that manner. Volcanic action contributed some carbon dioxide to the atmosphere, a prerequisite for the development of plant life. It was not until plant life became established in the oceans (mainly as blue-green algae) that much oxygen entered the atmosphere. At that time life was restricted to the ocean where it was protected from the ultraviolet rays of the sun. Oxygen was gradually liberated in increasing quantities by the process of photosynthesis, until the atmosphere was thick enough, and therefore protective enough, to allow life near the ocean surface. The rate of oxygen accumulation increased markedly at this point; but throughout most of the Precambrian, the oxygen available was sufficient only to support metabolism carried out by single-celled creatures. About 2.1 billion years ago, atmospheric oxygen reached its first peak – a critical level was reached when oxygen made up about 1% of its present level. At this point ozone began to form – another critical milestone necessary for life to continue to develop and, in later periods, to move on to land. Once the protective ozone layer was established and plants and animals moved on to land, the atmosphere as you know it today was well on its way. How can geologists peg this increase in oxygen to that time? A common worldwide red sandstone has been dated to 2.1 billion years. The component that makes the stone reddish is oxidized iron (basically rust). There had to be adequate amounts of oxygen in order for the iron from the rocks being eroded to oxidize. It is putting this "two-plus-two" together that has let scientists piece together Earth's geologic history. This description of the development of the Earth's atmosphere illustrates the fact that life has not been evolving against a static background and atmosphere, but that dozens of interrelated processes and cycles have been evolving together, affecting each other on the way.

The Precambrian stretches for a very long period of geologic history. Just imagine the amount of change that the Earth's surface must have undergone with uplifts, volcanism, tectonic plates shifting, erosion, glaciation, and so on. But life continued to evolve, becoming more complex, so that in the later Precambrian, abundant life was in the oceans. Many non-microscopic invertebrates began to appear at the end of the era. Worm burrows have been discovered in Nevada rocks dated at one billion years old. In southern Australia, in rocks dated at 680 million years, are fossils of more than 34 species that include jellyfishes, worms, sponges, sea pens, coral-like animals, primitive arthropods, and various tracks and trails. Many of these animals were several inches long. Such large animals needed an atmosphere rich in oxygen, perhaps 10% of the amount present today.

Originally the division between the Precambrian and the Cambrian, the first period of the Paleozoic Era, was the appearance of the fossil record, for at the time the division was made, no fossils had been found in the Precambrian rocks. The beginning of the Paleozoic, 570 000 000 years ago, was marked by a dramatic increase in life-forms that left many fossils in the fossil record. The first vertebrates and armoured fishes appeared, along with the first sea shells.

2. Why are there so few fossils surviving from the Precambrian Era? Discuss in terms of types of life-forms and in terms of the characteristics of the era itself.

3. Using Table E.3 on pages 554 to 556 of *Visions* 2, you may wish to go back to your chart in question 1 and add more information to it. Only add major developments in the fossil record.

VISIONS

Check your answers by turning to the Appendix, Section 2: Activity 1.

Paleozoic Era

Table 2.2 gives the major events, fossils, and developments in each period of the Paleozoic Era. Many of the points made here do not appear in Table E.3 in your textbook.

TABLE 2.2 MAJOR EVENTS, FOSSILS, AND, DEVELOPMENTS IN EACH PERIOD OF THE PALEOZOIC ERA

Period	Years Past	Events, Fossils, Developments
Cambrian	570 000 000	• lasted 65 000 000 years • named for rock formations first described in Cambria, Wales • Almost all major groups of living things appeared.

		• Areas you know as southeastern US and Mexico were near the South Pole while the equator passed through northern Canada and the western US. (This was before the supercontinent Pangea – before continents developed as we know them today.) • trilobites very common and serve as important fossils to correlate strata worldwide • no terrestrial life • ended with mass extinction of 75% of trilobite families and 50% of all sponges, as well as many other animals • ended with major drop in sea level, with much erosion occurring in North America
Ordovician	505 000 000	• lasted 67 000 000 years • Collision of North American plate with Europe and Greenland plate caused mountain-building in Eastern US, the beginning of the Appalachian Mountains. • brachiopods very common • Echinoderms (such as starfish) appeared. • The very important corals appeared for the first time. • The first vertebrates appeared – small bone-plated fishlike creatures related to today's lampreys and hagfish. These are the ancestors of all other vertebrates. • The ozone increased, making the Earth's land surface safer for life. • A few plant fossils have been found, possibly indicating life on land. • ended with another mass extinction, with 25% of all families perishing

Silurian	438 000 000	• lasted 33 000 000 years • The northern supercontinent and the southern group of continents moved closer to each other. • heavy volcanism, lava flows, and ash • heavy erosion in the many uplifted areas • heavy deposition in the sinking areas • some simple land plants • Some millipede-like fossils may have been terrestrial.
Devonian	405 000 000	• lasted about 45 000 000 years • abundant and varied sea life • North America and Europe still together • Appalachians completed. • Equator ran from northern BC to Newfoundland. • corals very prolific reef builders • Arthropods (millipedes and scorpions) moved to land. • early land spiders • major fishes, of all modern types • amphibians abundant, very similar to modern • major land plants – huge ferns and the first seed-bearing plants • ended with a mass extinction – 25% of all families, including almost all fishes and amphibians, and 50% of the corals and trilobites

Carboniferous	360 000 000	• lasted about 80 000 000 years • In American books, it is divided into the Mississippian and the Pennsylvanian periods. • Most of North America was underwater early in this period, leading to major limestone deposits. • large crinoid population • Single-celled foraminiferans were abundant; some limestone layers made up almost completely of their skeletons. • all continents together later in period to form Pangea • Most of the continent was covered with massive swamps with huge trees, creating most of North America's important coal deposits. • major insect population, some the largest that ever lived • first reptiles develop (first animal to live entirely on land; fossils found in Nova Scotia
Permian	280 000 000	• lasted about 35 000 000 years • formation of supercontinent Pangea continues, plates colliding further to cause uplift of southern Appalachians. • some seas in west of present-day North America, but large areas of dry land • Drier climate causes primitive plants to decrease and gingkos and conifers to increase. • rich fossil record of amphibians and reptiles with new lizard-like reptile (the pelycosaurs) with a "sail-like" fin on its back

		• Therapsids developed from some pelycosaurs. These mammal-like reptiles colonized areas close to the poles, suggesting they may have been warm-blooded and/or have fur. These were the ancestors of later mammals. • Mass extinctions occurred at end of Permian with 96% of all existing species perishing, most in the sea but also 75% of amphibian and 80% of reptile families. Many plants also became extinct. The cause is unknown.

The mass extinction at the end of the Permian period marks the end of the Paleozoic Era, while the appearance of the dinosaurs is the marking the beginning of the Mesozoic Era.

ISIONS

4. You may have noticed some discrepancies between the information in Table 2.2 and Table E.3 in your textbook.

   a. Point out two of the discrepancies. Explain why these discrepancies might occur.

   b. What does this suggest about the science of geology, and the process of science as a whole?

5. Considering the partial geologic column you have studied so far, what do you see as the major developments in the Precambrian and Paleozoic Eras that were crucial in leading to the Earth and its inhabitants we know today ?

6. A number of explanations that have been put forth as to the cause of the mass extinction at the end of the Permian period follow. Draw on your knowledge of geology, stratigraphy, and relationships and patterns of development as shown in the geologic tables and charts, to think like a paleontologist and discuss the pros and cons of each explanation. What are the strong points in favour of each theory? What are the weak points? (To this point no explanation has been put forth that satisfactorily explains the major extinction in the Permian period.)

   a. There was a sudden, drastic drop in sea level.

   b. The formation of the supercontinent, Pangea, toward the end of the Paleozoic Era allowed species from each continent to compete with each other, leading to their extinction.

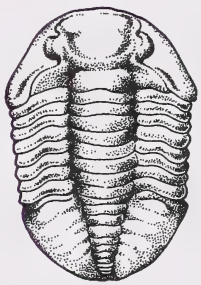
   c. The climate changed.

Check your answers by turning to the Appendix, Section 2: Activity 1.

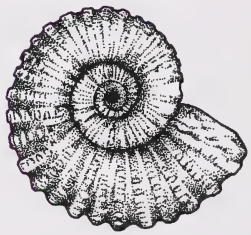
The principle of faunal succession that you were introduced to in Section 1 plays a significant role in establishing the geologic column and in interpreting fossils and the chronology of life. You have seen in the charts and tables that life developed from simple, one-celled organisms into multi-celled, increasingly complex life-forms. Fossils of increasingly complex life-forms correlate with increasingly newer rock strata. More detailed study of some of these fossils will give you a better understanding of the worldwide correlating of rock strata to develop the complete geologic story of Earth's surface. Check out Plate 2.4 on page P-5 of *Visions 2* for pictures of four common zone fossils.

VISIONS

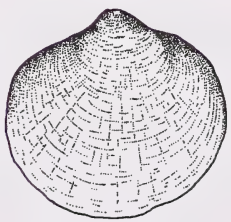
Zone fossils are markers that allow scientists to match up corresponding strata around the globe. A good zone fossil is from a species that was extremely plentiful, spread around the globe as much as possible, left well-preserved remains, and died out reasonably soon so it would be limited to a few rock layers. Here are four important zone fossils:



Trilobites (three-lobed) were marine segmented arthropods, markers for rocks 590 to 510 million years old.



Ammonoids were cephalopod mollusks with coiled, flat, wrinkled shells, markers for rocks 370 to 65 million years ago.



Bivalves are mollusks with hinged, two-part shells, zone fossils for rocks 370 to 65 million years ago.

Foraminiferans are tiny, single-celled organisms drifting in the sea and forming limy shells, markers for rocks 65 million years to present.

Key fossils help geologists date rock layers disturbed by faults, folding, and unconformities. Note in Figure 2.8 how the fossils are used to correlate and match up rock layers that have been changed from the original horizontal layers of deposition. In diagrams A and B the layers that contain the same fossils were once on the same horizontal level, but the layers in A were moved from their original positions by faulting, while the layers in B were affected by folding. For example, in diagram A the three carboniferous starfish labelled e were all on the same level at one time. The centre section may have been pushed up while the section on the right may have dropped.

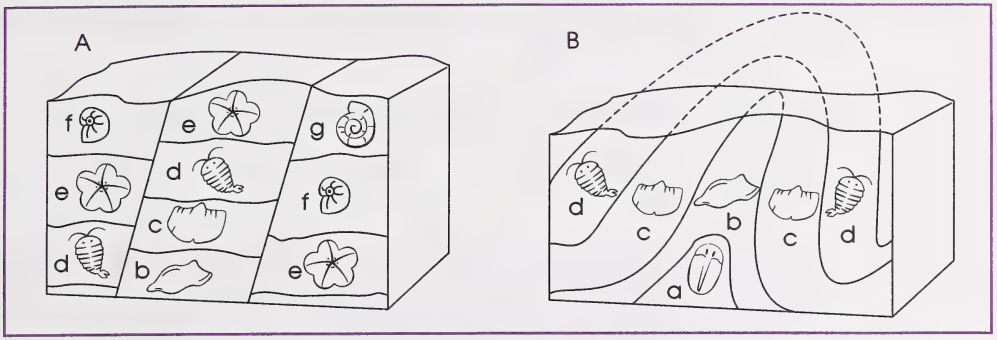


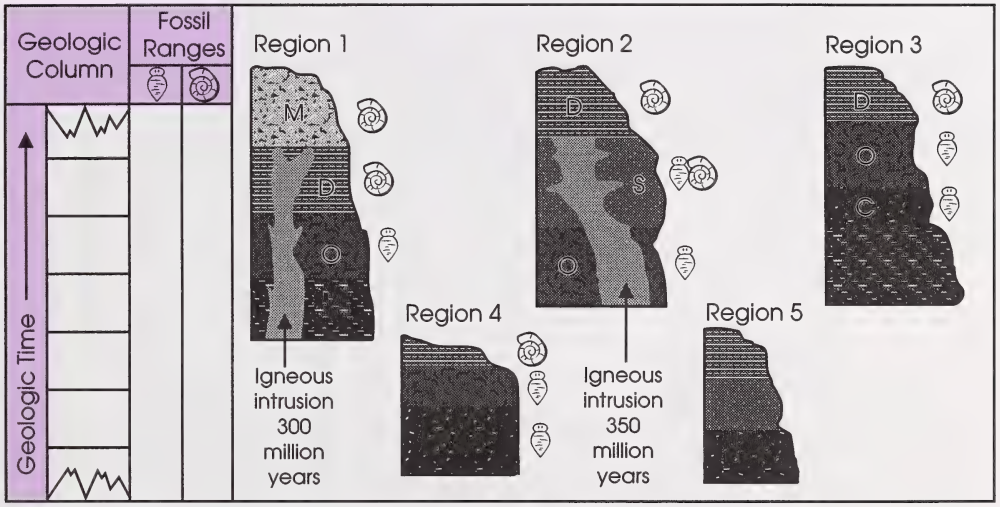
FIGURE 2.8 Using Fossils to Match Unconformities

The following zone fossils are present in diagrams A and B at various levels.

a – Cambrian trilobite
b – Ordovician crinoid (sea lily)
c – Silurian brachiopod (lamp shell)
d – Devonian sea scorpion
e – Carboniferous starfish
f – Permian ammonoid
g – Triassic ammonite

The younger fossils are present in the top layers, while the older fossils are present in the bottom layers.

Examine the following diagram; then answer questions 7 to 10.



7. Reproduce the geologic column and fossil range column at the left of the diagram. Using the laws of stratigraphy, arrange the letters representing periods in proper order in the geologic column.

8. Use lines to plot the vertical ranges of the two fossils to show the strata or layers in the geologic column over which each fossil extended.

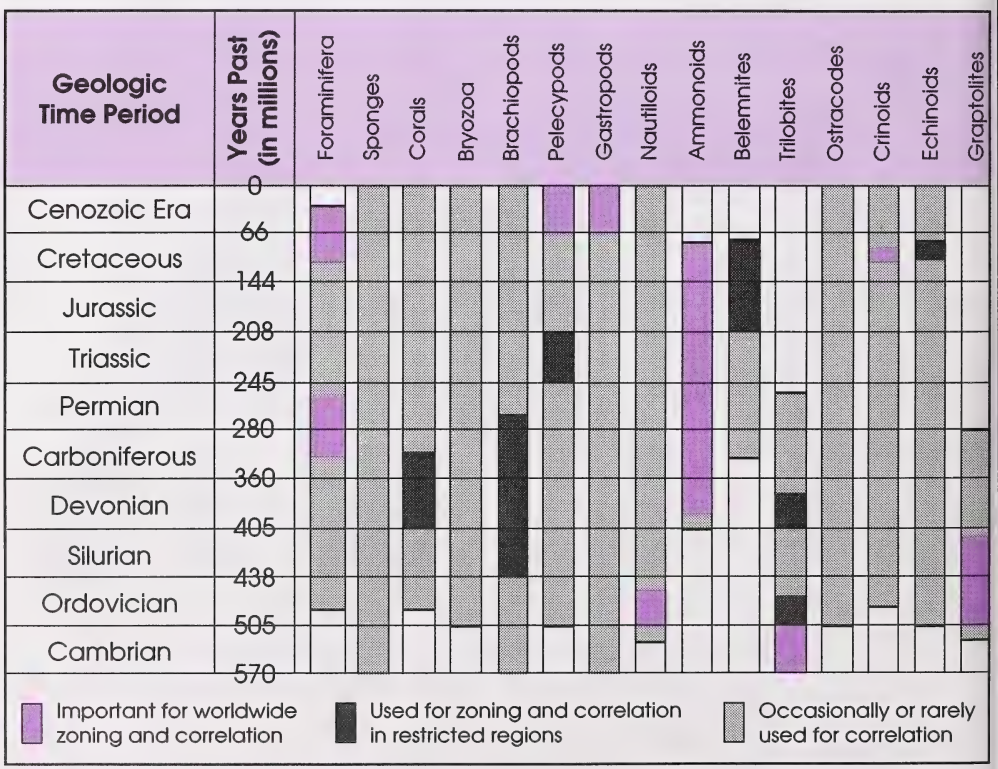
9. a. During which of the hypothetical periods were the rocks in unexplored Region 4 deposited?

   b. In which periods were rocks in Region 5 deposited?

10. What statement can you make regarding the age in years of the rocks in Region 4? in Region 5?

Check your answers by turning to the Appendix, Section 2: Activity 1.

Now move on to some questions that tie together your knowledge of stratigraphy and faunal succession with the eras and periods you have been studying. The diagram shows the geologic ranges of some major groups of marine invertebrates and the importance each has in the correlation and age determination of strata of the various periods. The individual periods are not to scale. When estimating the date in a particular period, take note of how many millions of years are represented in that period. Use the diagram to answer questions 11 to 17 that follow.



11. If trilobites are found in a rock strata, within what limits may the age of the rock be stated?

12. If the belemnites and trilobites are found together in a rock strata, within what limits may the age of the rock be stated?

13. If belemnites, trilobites, and graptolites are found together in a rock strata, within what limits may the age of the rock be stated?

14. For age determination of a rock strata, what are the advantages of having a number of zone fossils over a single kind of fossil?

15. a. Pelecypods and gastropods are most useful for worldwide zoning and correlation of rock strata of what age?

    b. For what periods are nautiloids most important for worldwide zoning and correlation?

16. What are the reasons that some fossils are very important for zoning and correlation while others are not useful?

17. It is sea organisms that provide most zone fossils. Explain why this is so in terms of the traits that make a good zone fossil.

Check your answers by turning to the Appendix, Section 2: Activity 1.

ISIONS

Return to Table E.3 on pages 555 and 556 of *Visions 2* and read about the Mesozoic and Cenozoic Eras. Note the major developments in each period and how much more detail appears in the fossil record the closer to the present day it becomes.

Mesozoic Era

The Mesozoic Era, with its three periods reaching from 245 000 000 to 66 000 000 years ago, is best known for its dominant life-forms, the reptiles, especially the dinosaurs. Its first division is the Triassic Period. Not many plant developments are recorded in the Triassic fossil record, but the Petrified Forest in Arizona is one that shows the dominant plants there to be conifers, with a few ferns. The presence of conifers suggests a fairly dry climate. At the end of the Triassic another mass extinction occurred, particularly affecting ammonoids and brachiopods. Amphibians and reptiles were also decimated. The first true mammal fossils are found in very late Triassic to early Jurassic strata. These animals, about the size of mice, managed to survive the mass extinction.

At the beginning of the Jurassic, the supercontinent Pangea began to break up, with Africa and North America beginning to pull apart and Gondwanaland moving away from the southern border of North America. The West Coast was very active tectonically, but in the western interior of the continent a major formation was being deposited. This deposit of sandstone, siltstone, and shale covers millions of square kilometres and includes almost all of the large dinosaur fossils found in North America. Many plant and primitive mammal fossils were also deposited there. Saurichian dinosaurs (which walked on two legs) increased in size. Ornithischian (bird-hipped) dinosaurs developed. Ichthyosaurs and plesiosaurs dominated the seas while pterosaurs were in the skies. Archaeopteryx, the first fossil birds and the ancestors to modern birds, appear in Jurassic formations of southern Germany. Fossils from six mammal orders appear in the Jurassic.

The boundary between the Jurassic and the Cretaceous is marked by widespread unconformities, caused by erosion that followed after a drop in sea level. The Cretaceous Period is marked by the depositing of more rock strata than any other period. What might be the reasons for this? This is a relatively recent period, so erosion had not as much chance to remove the layers. It was also one of the longer periods, lasting about 70 000 000 years. But most importantly, the seas stood higher on the continents than ever before or since, allowing for thick rock deposits to be laid down. Much of this was caused by the Earth's plates moving rapidly, causing the continents to sink as the plates pulled apart. The Rocky Mountains began to rise during the Cretaceous, causing much folding and faulting in the strata as it was being uplifted to form the range. Corals were widespread in this period, adding to what would later become some of Alberta's oil and gas fields. Mesosaurs, huge marine reptiles, dominated the seas, while pterosaurs continued in the skies. A wide diversity of dinosaurs inhabited the land until wiped out in a mass extinction at the end of the Cretaceous. This mass extinction of over 50% of the Earth's animal families is the marker between the Mesozoic and Cenozoic Eras.

Read the following news articles which detail recent developments into research on the cause of this mass extinction. The first appeared in *The Edmonton Journal* on October 24, 1993.

'Wave' tracked to giant crater by geologist

Clues to death of the dinosaurs found despite scientific skeptics

Shelley Page
Ottawa Citizen

Sweeping aside slick muck and brown silt on the banks of a Texas river, graduate student Alan Hildebrand wondered if he'd unearthed his first clues to an ancient catastrophe. Exposing a 65-million-year-old formation, the Canadian was surprised to see a chaotic jumble of rocks. He believed it was the faint fingerprint of a wave, a wave as tall as the ocean is deep, a wave that rolled across the Earth millions of years ago, tearing up the ocean bottom and depositing debris thousands of kilometres away. A wave perhaps caused by an asteroid or comet slamming into the Earth somewhere nearby.

"It was extraordinary. Deposits like this don't occur anywhere else in the world. A big boulder thrown up into the ancient sediment. And I wondered if it was an impact wave," says the geologist, now working at the Geological Survey in Ottawa.

This small discovery in 1988 inspired

Hildebrand, 38, to doggedly seek proof that an asteroid or comet had collided with the Earth somewhere between North and South America at the end of the Cretaceous period – the time when dinosaurs became extinct.

He's visited more than 60 sites hunting the crater. As a student at the University of Arizona, he often spent his own money and time digging up clues, only to have his findings shot down repeatedly by skeptical leaders in his field. They insisted he was on the wrong track.

"I was a graduate student who couldn't get anything published. They said my work was fantasy."

Six years later, not only has Hildebrand proven to the satisfaction of almost everyone that there was a collision, he has found the site – a large crater buried beneath one kilometre of sediment on the Yucatan Peninsula in southern Mexico.

Now, instead of debating its existence, geologists are trying to determine how big and how lethal the impact was. Did it cause the extinction of dinosaurs?

Plastic bags filled with rocks and sediment. It could be any geologist's office until you see the painting over Alan Hildebrand's desk. Two dinosaurs look up in fear at a skyscraper-tall wave poised to wash over them.

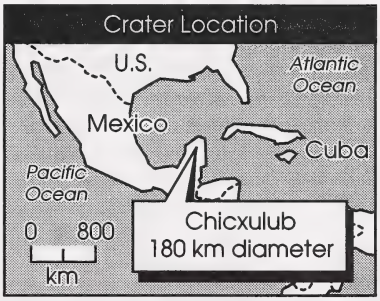
It's a small reminder of Hildebrand's preoccupation, one big burning rock that slammed into the Earth back when the dinosaurs roamed.

Many scientists, often dismissed as dreamers, have suggested that comets or asteroids might collide with Earth, causing mass extinctions. French scientist Pierre de Maupertuis in 1750 was the first.

But the search for the site of a collision did not begin until the late 1970s when an extremely rare layer of iridium was found like a bookmark between two chapters of Earth's history, one dominated by dinosaurs (the Cretaceous period), the other ruled by mammals (the Tertiary period). This iridium layer was dubbed the K-T boundary.

Although rare in the Earth's crust, iridium is plentiful in asteroids and comets.

The discoverers of the thin layer, geologist Walter Alvarez and his father Luis, the 1968 Nobel laureate in physics, suggested a startling idea: the iridium layer was the settled dust from the fireball of a meteorite impact.



More startling, they also suggested that the impact of the meteorite lofted enough debris into the atmosphere to block sunlight from the Earth, bringing photosynthesis to a halt. The world's ecosystems collapsed in the cold and dark, leading to widespread extinctions on land and in the seas.

Most doubted their claims, saying the iridium came from volcanoes. Besides, where was the crater?

A geologist with a degree from the University of New Brunswick, Hildebrand worked in northern Canada before enrolling at the University of Arizona to do his doctorate. In 1984 he began studying the thin layer of iridium that coated the planet.

"Almost without realizing it, I started looking for the impact site." While most geologists looked for a crater on land, Hildebrand thought the meteorite had splashed into the ocean. If so, massive waves might have washed up deposits on to the edges of the continents.

After combing scientific journals for mention of unusual K-T boundary deposits that could have been left by waves, he headed to the Brazos River site, not far from Waco Tex., in 1988.

"It turned out they missed something," Hildebrand says of the original excavators. In one part of the outcrop he noticed an 80-centimetre-long boulder just beneath the iridium-rich dust. He believed it was left by an impact wave. In the literature he found records of other such deposits.

He hoped to present a paper on the impact wave deposits at a meeting of geologists the same year, but it was rejected by the editor, crater geologist Virgil Sharpton of the Lunar and Planetary Institute in Houston. Over the next few years Sharpton would reject Hildebrand's papers several times, saying there was no proof of a crater.

So Hildebrand started looking for proof of a submerged crater around the Caribbean Sea.

While he was combing the literature he had noticed something else interesting. Underneath the fireball layer of iridium was a thick layer of clay.

Most people didn't think that it had anything to do with the impact, but Hildebrand wondered why it only occurred in the western hemisphere and was thickest in the Caribbean.

Hildebrand flew to Haiti. There, digging on a steep hillside, he found what he thought was the first concrete proof of an impact in a half-metre thick layer of greenish brown clay.

The clay was packed with tektites, small glassy rock shaped like dumb-bells and teardrops, formed when molten rock sprays out from the impact and the droplets congeal into glass. It also had quartz bearing the distinctive marks of intense shocking found only in rock blasted by giant impacts. They were the largest grains yet discovered and in quantities 10 times that of other K-T sites.

Hildebrand wrapped a 15-kilogram chunk of the fragile clay in a cement and burlap jacket and sent it back to the University of Arizona lab.

He thought this "ejecta" was formed when a meteorite slammed into the Earth.

At first this paper, submitted to the journal *Science*, was rejected, getting three negative reviews, including one from Sharpton. After much debate it was eventually printed.

"There was a great kerfuffle," Hildebrand says, as people debated whether this thick layer existed and what it might be.

Based on the thickness of the Haiti ejecta, Hildebrand was more convinced than ever that the crater lay between the continents. But where?

In March 1990, he heard of two geophysicists employed by Pemex, the Mexican national oil company, who a decade before had discovered an unusual circular magnetic and gravitational anomaly in the Yucatan. But there was no proper investigation because Pemex said it owned the data and drill core samples, most of which were destroyed in a warehouse fire.

Then serendipity stepped in. Hildebrand applied for a job at the Geophysical Survey of Canada to work with crater researcher Richard Grieve.

When Hildebrand walked in for his interview, he was taken aback by a wall map showing minor fluctuations in the Earth's gravitational field.

" I saw this beautiful horseshoe-shaped anomaly over the Yucatan and it was like 'holy cow'," he recalls. It was the evidence he needed.

Hildebrand and the Geological Survey's Mark Pilkington, who produced the map, submitted a paper to the journal *Nature*, saying the meteorite had landed over the Yucatan, then submerged under the shallow

sea that existed at the time. They say the meteorite, about 15 kilometres across, blasted an 180-kilometre-wide crater.

They called the gaping crater Chicxulub after the small village it's buried beneath.

The paper was rejected. Hildebrand looked for more proof.

It wasn't until Walter Alverez used carbon-dating analysis to show the impact was 65 million years old that the crater was fully accepted.

" It's very easy to jump on the bandwagon when something very intriguing comes along. But we get paid to be skeptical," says Sharpton, who did an about-face.

Not only does he believe there is a crater, he now says it's 300 kilometres in diameter – nearly twice as large as Hildebrand has thought. In a paper published last month in *Science*, he says Hildebrand missed a subtle outer ring.

Sharpton says his finding means the crater is a once-in-a-billion-years occurrence instead of a once-every-100-million-years occurrence.

Hildebrand says the evidence doesn't support the outer ring and Sharpton just wants to be "Mr. K-T boundary."

Now both scientists are working to prove they are right and their rival is wrong.[1]

Two weeks later another article appeared in the paper.

Panel disputes theory disaster killed dinosaurs

Most dinosaurs died out because of a series of events over millions of years, including reduced levels of the Earth's oxygen, not because a single meteor smashed into Mexico's Yucatan Peninsula 65 million years ago, a panel of scientists says.

"Extinction patterns, including that of dinosaurs, does not fit a single catastrophic event," J. Keith Rigby, Jr, a Notre Dame University paleontologist, told a news conference held during the American Geological Association.

Rigby and three other scientists on the panel posed the Pele Hypothesis – named for the Polynesian volcano goddess – to explain why most, but not all, dinosaurs went extinct, as well as other factors in the Earth's evolution.

Simply put, the hypothesis holds that dinosaurs thrived during a greenhouse effect at the height of the Cretaceous Period (Age of Dinosaurs 144 to 65 million years ago) when the Earth's temperatures were kept at a semitropical level from pole to pole by frequent eruptions of volcanoes.

The Pele Theory holds that those high temperatures were caused by "super plumes" – abundant volcanic activity in the western Pacific Ocean – producing high levels of carbon dioxide that kept temperatures high and increased levels of plant photosynthesis that maintained high levels of oxygen.

Once the volcanic activity – most of it below sea surfaces – drastically decreased, carbon dioxide also lessened so that oxygen levels and temperatures were reduced.

Dinosaurs' respiratory systems could not evolve to make up for reduced oxygen in the atmosphere.[2]

[1] The *Ottawa Citizen* for the article "'Wave' tracked to giant crater by geologist," by Shelley Page, October 24, 1993. Reprinted by permission of the *Ottawa Citizen*.

[2] *The Edmonton Journal* for the article "Panel disputes theory disaster killed dinosaurs," November 7, 1993. Reprinted by permission of *The Edmonton Journal*.

If even highly trained scientists – paleontologists and geologists – have very strong opposing theories about such events as the extinction of dinosaurs, who are you to believe? These articles show some very important points about the scientific process. Evidence of some event is found and some hypotheses are made to explain the evidence. Much conjecture is required, as well as the pulling and piecing together of the clues so they make some kind of logical explanation of the evidence.

Most often these hypotheses cannot be accepted immediately because the data and other evidence is usually quite sketchy and leaves a lot of gaps. More research is done by all camps in order to find more evidence to back up their particular views. Personalities and vested interests often play roles, too, as scientists vie for research dollars and recognition and acceptance by their peers. New evidence, new research techniques, new technologies, and piecing together of information in new ways may lead to one hypothesis being accepted more than the others, maybe becoming the accepted theory to explain particular events.

18. Based only on the material in the articles, which gives more hard facts to lend its views more credence?

19. List, in order, the steps Hildebrand followed to try to prove his hypothesis.

20. The article "'Wave' tracked to giant crater by geologist" contains this statement: "It wasn't until Walter Alvarez used carbon-dating analysis to show the impact was 65 million years old that the crater was fully accepted."

    a. Based on the information you studied on radioactive dating in Section 1, explain how this statement is in error.

    b. What might this suggest about the accuracy of evidence presented in media?

21. Explain how these two articles illustrate the scientific process in action.

22. The mass extinction of the dinosaurs was a very critical event in the development of life on our planet and one that paleontologists clearly are very interested in explaining as definitely as possible. Let your mind have free range. Develop a hypothesis in which you explain the mass extinction of the dinosaurs. In what areas would you need to research and what types of evidence would you need to obtain in order to support your hypothesis? Present any existing evidence that already supports your hypothesis.

Check your answers by turning to the Appendix, Section 2: Activity 1.

Cenozoic Era

You have one era left to study. The Cenozoic ("Time of Recent Life") began with the extinction of the dinosaurs and the emergence of mammals as a dominant life-form. So much information has been gathered about the last 65 000 000 years that the Cenozoic has been divided into the Tertiary Period, subdivided into five epochs, and the Quaternary Period, with two epochs. Refer again to Table E.3 on pages 555 and 556 of *Visions 2* and review the information on the Cenozoic Era. Then answer these questions.

VISIONS

23. What changes to the continents, caused by the movement of the Earth's plates, occurred during the Cenozoic Era?

24. What were the important developments in life-forms during this era?

25. What changes occurred in climates during this era?

26. Why are there so few rocks of Cenozoic age?

27. What would you predict will be the next major geologic events that might usher an end to the Holocene Epoch, or even the Quaternary Period, or even more dramatically, the Cenozoic Era? Upon what evidence do you base your prediction?

Check your answers by turning to the Appendix, Section 2: Activity 1.

Inferences from Fossils

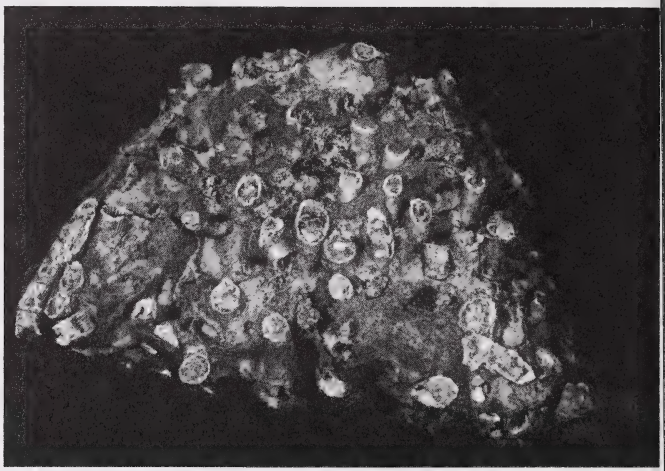
Some details have been presented previously in which characteristics of life-forms and of the climates in which they lived were inferred from particular fossils. For example, a large number of conifers as compared to ferns in the fossil record suggests at the time that strata was being deposited, the climate was relatively dry. Other details in the fossil record might help **paleobotanists** to determine if the climate was temperate or hot and dry, and whether the trees preserved in that deposit grew at low or high altitudes. Of course, much of the piecing together and interpreting of such clues is based on paleobotanists' understanding of behaviours and interrelationships of modern plants in the variety of ecosystems on today's globe. And so it is with the inferences made about other areas of the fossil record. *The present is the key to the past.*

paleobotanists – scientists who study fossil plants

Each organism is limited to a certain area in which conditions exist that are suitable for its survival. An organism eats a restricted variety of foods, sometimes limiting its diet to members of a single species. The organism is adapted to a particular mode of life and its body is designed so it is able to capture its food in the most efficient manner. Birds, for example, have beaks specialized to best handle their diets – whether worms, insects, nuts, seeds, and so on. Body features and ways of life of organisms are closely related to different conditions of temperature, soil, quantity of water, water salinity, light, and food supply.

symbiotic relationship – a relationship between two or more species that live in close association

Coral reefs provide a good example for study. Coral has a close **symbiotic relationship** with algae and so demands some very specific environmental conditions. It is limited to shallow well-lit waters where the algae can carry on photosynthesis. The reefs flourish only in tropical sea water where temperatures are between 25°C and 29°C. They also have high oxygen requirements provided by the moving currents close to shores. Fossil reefs formed from corals are common in strata from the Silurian, Devonian, and Lower Carboniferous periods. The photograph that follows shows fossilized coral.



THE ROYAL TYRRELL MUSEUM/ALBERTA COMMUNITY DEVELOPMENT

By tracing the locations of the fossilized coral reefs, paleontologists can map the moving shorelines of the ancient seas. And, of course, the scientists know then that the sediments were laid down in tropical seas with temperatures between 25°C and 29°C. Much of Alberta has strata of these periods that include the fossilized coral reefs. Thus, Alberta once had a tropical climate, and was a shoreline to an ancient sea. Other questions do come into play, though. Were the deposits actually deposited in this location (in terms of latitude and longitude), or were the deposits laid down in some other location and moved here through tectonic forces? Other evidence is then studied to answer those questions. These fossilized coral reefs, by the way, prove very important in locating Alberta's oil and gas deposits in the Silurian, Devonian, and Carboniferous strata. More on fossil clues will be studied in later activities.

28. In 1988 members of the Canada-China dinosaur project discovered in the Gobi Desert the fossils of a group of five baby ankylosaurs, each the size of a small sheep, huddled in a petrified sand dune. Answer the following questions to discover what information could be revealed by this find.

    a. What was the climate when these ankylosaurs died as suggested by this find?

    b. What could be the reasons for five baby ankylosaurs being found in the one location?

    c. Other sites containing multiple ankylosaur fossils were also located. What could this suggest about social behaviour of these dinosaurs?

Check your answers by turning to the Appendix, Section 2: Activity 1.

In Activity 1 you discovered how fossils and rock layers are correlated, how scientists piece evidence together to support a hypothesis, and how evidence can be inferred from fossils. In the next activity you will read about The Royal Tyrrell Museum of Palaeontology in Drumheller, Alberta, and the work they do in fossil collection, preservation, and interpretation.

Activity 2: Paleontologists – Fossil Hunters

Alberta is a rich source of fossils and the province's museums have long been leaders in paleontological pursuits. The Provincial Museum of Alberta and the major petroleum and mining companies operating in Alberta were long the major players in collecting geological and fossil data and specimens from Alberta's rock formations. The world famous Royal Tyrrell Museum of Palaeontology consolidated much of this work at its facilities in Drumheller and Dinosaur Provincial Park. Scientists from the Tyrrell Museum lead teams in field research, collection, display, and interpretation of all types of fossils, although their dinosaur work is probably the most famous. The photograph that follows shows a dig in Dinosaur Provincial Park near Drumheller, Alberta. What are the processes of fossil collection and display?

THE ROYAL TYRRELL MUSEUM/ALBERTA COMMUNITY DEVELOPMENT

Finding fossils of some sort is not difficult in Alberta. The badlands of the Red Deer River at Drumheller and Dinosaur Provincial Park are rich hunting grounds, but most other areas will also yield specimens. The Rocky Mountains present many layers of exposed strata that are rich in fossils, especially marine samples. Coal is present across widespread areas of the province. You may also find fossils wherever strata are being exposed by some means, whether by road or railroad cuts, gravel pits, mines or quarries, construction sites, or river banks and canyons. Avid rock and fossil collectors visit as many of these sites as possible. Maps and information on productive collecting areas in Canada are available from

Geological Survey of Canada
Natural Resources Canada
601 Booth Street
Ottawa, Ontario
K1A 0E8

Local rock and fossil collector clubs can provide you with a wealth of information about good collecting sites in your local area. When you go exploring for or collecting fossils, always respect private property and be aware of safety concerns.

How to Collect and Preserve Fossils

The process of removing a fossil from its site varies according to the condition of the fossil and the type of sedimentary rock in which it is located. In many cases the fossil will already be weathered away from the surrounding rock, but more often the fossil will be embedded in a bed of rock. If the rock is fairly small and loose, score the rock with three or four lines that frame the specimen leaving a generous margin around the fossil. Place the rock on another base rock and tap the outer scores with a hammer. The rock should split neatly and fall away. Continue scoring and tapping until close to the fossil. If the fossil is still part of the main rock face, you must chip a trench around the fossil, angling your chisel away from the fossil. When the trench is at least 1.5 cm deep, angle the chisel toward the fossil, give it a sharp blow, and the fossil should loosen. Always record the location in which the fossil was collected, and identify the rock formation as accurately as possible.

The fossil then needs protection in transport to your home or to the workshop of a museum. If the surrounding shale or sandstone is crumbly, the fossil itself may be in danger of disintegrating. A special mixture, such as heavily thinned cement glue or a professional spray, needs to be painted on the fossil to protect it. Fossils of carbon film are in danger of flaking off the rock layer if they dry out. Sprays are used to fix them or the specimens are kept moist until they are home where they can be safely dried and fixed by a plastic spray.

ilicified – onverted into or lled with silica

Once in the workshop, the fossil is prepared for display. Many fossils need only to be washed in water to remove soil or mud, but proceed cautiously for some fossils will disintegrate. Acetic acid (vinegar) may be used to dissolve limestone around **silicified** fossils. But again be careful, for many fossils themselves are composed of calcium carbonate, and will dissolve. The most common kind of preparation is the removal of bits of rock attached to the specimen. This is done using fine chisels, picks, or needles. There is almost always a plane of weakness between a fossil and the surrounding rock which allows the rock to be flaked off. If you are dealing with a fossil mould, you can make a cast by filling the hollow with latex and pulling it out. If you wish to duplicate the fossil in plaster, paint the cast with a thin layer of latex and remove it. Support it in sand or aluminum foil and pour plaster into it. When the plaster is hard, remove the latex and the plaster cast will resemble the original fossil.

The best system for storage of fossils is a set of wide shallow drawers where each fossil is kept in a separate cardboard box, labelled with its scientific name, the location where it was collected, and the formation in which it was found. Of course, a museum will put its more dramatic, rare, and special fossils on display. See Plate 2.5 on page P-6 of *Visions 2* to see some of the displays at The Royal Tyrrell Museum of Palaeontology.

VISIONS

In the following investigation you will collect your own fossils, examine fossils from a collection, or examine fossils in photographs.

Investigation: Performing Field Research

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

PATHWAYS

If you are able to collect your own fossils, do Part A. If you have access to a public or private collection of fossils, do Part B. Otherwise, do Part C.

VISIONS

Read Activity 2.4 on pages 69 to 72 of *Visions 2*. You will need reference materials to help classify your fossil. You may obtain pamphlets and other materials from the following:

The Royal Tyrrell Museum of Palaeontology
Box 7500
Drumheller, Alberta T0J 0Y0

Geological Survey of Canada
Energy Mines and Resources
3303 – 33 Street NW
Calgary, Alberta T2L 2A7

Institute of Sedimentary
and Petroleum Geology
Energy Mines and Resources
3303 – 33 Street NW
Calgary, Alberta T2L 2A7

Provincial Museum of Alberta
12845 – 102 Avenue
Edmonton, Alberta T5N 0M6

Dinosaur Provincial Park
Box 60
Patricia, Alberta T0J 2K0

Department of Geology
1 – 26 Earth Science Building
University of Alberta
Edmonton, Alberta T6G 2E3

Other resources may be located in local municipal or school libraries. Some excellent resources for fossil identification include the following titles:

- *The Audubon Society Field Guide to North American Fossils*, published by Alfred A. Knopf
- *The Field Guide to Prehistoric Life*, published by Facts on File Publications
- *Grzimek's Encyclopedia of Evolution*, published by Van Nostrand Reinhold Company
- *Index Fossils of North America*, published by John Wiley & Sons
- *Treatise of Invertebrate Paleontology*, published by the University of Kansas Press

Science Skills
- ☑ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Part A

Purpose

Perform the processes of fossil collection, display, and identification.

Carefully read the planning section of Part A on pages 69 and 70 of *Visions* 2.

VISIONS

Materials

The materials are listed on page 70 of your textbook and some of the resources mentioned earlier in this activity.

Procedure

Follow the steps in the Procedure section on pages 70 and 71 of your textbook.

Observations

Follow the Observations section on page 71 of your textbook.

Analysis and Interpretation

1. Do questions 1 to 4 on pages 71 and 72 of *Visions* 2.

Check your answers by turning to the Appendix, Section 2: Activity 2.

End of Part A

Science Skills
- ☐ A. Initiating
- ☐ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Part B

Purpose

Study a fossil collection and identify one fossil.

Read the planning paragraph at the start of Part B on page 71 of your textbook. You will have to find the location of a fossil collection and visit it.

VISIONS

Materials

The materials are listed on page 71 of *Visions 2* and some of the resources mentioned earlier in this activity.

Procedure

Follow the Procedure section on page 71 of *Visions 2*.

Observations

Prepare a visual display which could include diagrams, photos, or a videotape of your observations of the fossils.

Analysis and Interpretation

2. Do question 1 in the Analysis and Interpretation section of Part A.

Check your answers by turning to the Appendix, Section 2: Activity 2.

End of Part B

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Part C

Purpose

Study fossil photographs and identify fossils from the photographs.

Materials

- hand lens
- photographs numbered 4, 5, and 6 from the loan kit
- paper and pencil
- some of the resources mentioned earlier in this activity

Procedure

Step 1: Examine each photograph closely.

Step 2: Study your resources carefully for any information which will help you identify the fossils in the photos.

Step 3: Compare your fossil photographs to sketches or photographs in the resources to help you possibly match the fossils in your fossil photographs with those in the resources.

Observations

3. Make detailed sketches of each fossil, pointing out special identifying features of each.

Analysis and Interpretation

4. Identify each fossil. Explain the basis on which you made the identification.

Check your answers by turning to the Appendix, Section 2: Activity 2.

End of Part C

The Royal Tyrrell Museum of Palaeontology

The Royal Tyrrell Museum of Palaeontology shown in the following photograph was constructed on the site of several digs about 6 km northeast of Drumheller, Alberta.

THE ROYAL TYRRELL MUSEUM/ALBERTA COMMUNITY DEVELOPMENT

VISIONS

What all does The Royal Tyrrell Museum of Palaeontology do to deserve its reputation as one of the world's leading players in paleontology? Read pages 72 to 74 of *Visions 2* which give some detail about the museum's activities and Joseph Burr Tyrrell for whom the museum was named.

5. Briefly describe two of the major jobs for which The Royal Tyrrell Museum of Palaeontology is noted.

6. a. What are the major areas of research at the museum?

   b. Which area interests you the most? Why?

7. What is the Dinosaur Project?

8. Why is it important to study and compare fossils from around the world?

Check your answers by turning to the Appendix, Section 2: Activity 2.

The research section of the Royal Tyrrell is subdivided into programs based on the types of fossils being studied. These studies focus in the areas of vertebrate, invertebrate, plant, and rock strata paleontology. The museum has many visiting scientists and students who also do research in their particular fields of paleontology. Information is shared with scientists around the world to develop a more accurate picture of the Earth's history.

Of the programs conducted at the Royal Tyrrell, perhaps the most famous is the Dinosaur Project, the joint Alberta-China study in which Dr. Phil Currie and his team worked with Chinese teams in the Gobi Desert to unearth rich fossils beds providing new information in a number of areas. This project received a great deal of media attention. Read the following article about some of the Gobi Desert experiences which is reproduced from the May/June 1992 issue of *Equinox*.

In Search of THE DRAGON

The exposures are a half-hour drive from our camp at Bayan Manduhu along a rugged, twisting Gobi desert track that crosses dried-up riverbeds and two northern extensions of the Great Wall of China. This far from the Middle Kingdom, the Great Wall is not so great: little more than parallel ridges of loose gravel stretch from one shimmering horizon to the other. The ridges look ridiculously ineffectual until you try to climb them. The loose gravel is the Gobi's trademark–a *gobi*, in Mongolian, is a smooth, flat stone. As we drive, we pass herds of wild camels, an eagle perched on a low thornbush and a flight of ghostly gazelles that suddenly veer across our path at a hundred kilometres an hour.

About halfway there, we stop to let off Dave Eberth. An athletic and deeply tanned Albertan in his late thirties, Eberth is The Dinosaur Project's geologist; he spends his days on the open desert, mapping the ancient outcrops and trying to piece together the story of their formation. The Gobi's geology in this area has never been properly mapped, and unless you know something about where a dinosaur skeleton comes from, finding it is useless. Eberth carries a custom-made surveyor's staff and a backpack with two water bottles and a geologist's hammer dangling from it. He is wearing a fluorescent lime-green baseball cap and a blue bandanna and looks like a wild-eyed prospector as he disappears around a dune of pebbly sand.

The rest of us drive on. The desert is a complex interplay of hard light and soft

colour, of gently undulating dunes sifting around jagged outcrops of upthrust stone. The road weaves between ever-shifting hills of fine sand mixed with coarse gravel held together briefly by plants so tough that not even camels will eat them. There are six of us in a red four-wheel-drive vehicle. Phil Currie, from the Royal Tyrrell Museum of Palaeontology, in Drumheller, Alberta, is in the front seat beside the driver. He is one of the world's foremost dinosaur experts and probably the main reason we are in Inner Mongolia. He has been on his way here ever since he was 11 years old: two days after reading Roy Chapman Andrews' book *All About Dinosaurs*, an action-packed account of Andrews' bone-hunting expeditions to various exotic regions of the world, Currie told his parents that he was going to be a palaeontologist. They thought he had said pathologist and did nothing to dissuade him. "Dinosaurs," Andrews wrote, "were the strangest animals that ever existed on this earth. They were the sort of creatures you might think of as inhabiting another planet or the kind you dream of in a bad nightmare."

For Currie, the most fascinating of Andrews' adventures was his Central Asiatic Expedition into Mongolia, a trek that ran almost annually from 1922 to 1930. Andrews and his team of scientists from the American Museum of Natural History explored deep into the Gobi desert, which stretches east and west through the centre of Mongolia for 2000 kilometres.

It was perhaps to be expected, then, that Currie as a young palaeontologist at the Provincial Museum of Alberta, said, "Mongolia," without a moment's hesitation when his friend Brian Noble asked him in 1982 where he would most like to go to hunt dinosaurs. Noble, who had worked as a naturalist in Alberta's Badlands Provincial Park, was trying to come up with a project that would put Canada on the global dinosaur map.

So here we are in the sand and gravel Gobi desert, surrounded by stunted saxaul and bean caper bushes, Bactrian camels and tame-looking donkeys, hunting for dinosaurs. Behind Currie sits Don Brinkman,

THE EX TERRA FOUNDATION/MIKE TODOR

the Tyrrell's turtle expert, wearing a straw hat and a Tyrrell Museum T-shirt that says "Hell ain't a mile off!" Mike Todor and I, both from the Ex Terra Foundation, the Edmonton organization that Noble created to sponsor what has become known as The Dinosaur Project, share the seat with Brinkman, and behind us are Dong Zhiming and Qiu Zhanxiang, two of China's top palaeontologists. Dong, in his mid-fifties, has spent half his life in one dinosaur quarry or another and has named more new species than any other living palaeontologist.

Noble organized Ex Terra and The Dinosaur Project the same year that he first talked to Currie about it, arranging a five-year exchange of palaeontologists through Zhang Meeman, then director of China's Institute of Vertebrate Palaeontology and Palaeoanthropology (IVPP). Zhang was delighted with the deal: China is dinosaur-rich but cash-poor. "Quite frankly," she told me during our stopover in Beijing, "we could never have mounted such a large-scale expedition alone, even into our own country." Noble raised more than $7 million over the life of the project, handing the IVPP $100 000 each a year from 1987 to 1990 to cover the expenses of a two-month field season in Inner Mongolia – more than Y 400 000 to an organization whose normal research budget for each of its handful of scientists is less than Y 600 a year. Joining with Canada also gave the Chinese a chance to study in another dinosaur-rich country with some of the world's leading scientists. After China's Cultural Revolution, top scientists were in short supply. "I should tell you the truth," Zhang said. "My colleagues are not as strong as the Canadian scientists are. I wanted to have this joint project so that our scientists could learn from yours."

Every year for five years, a team of Chinese palaeontologists led by Dong and Zhao Xijin came to Canada to hunt for fossils in Alberta's badlands and on various islands in the Canadian Arctic. And every year, a similar team of Canadians under Currie and Dale Russell, a curator at the Canadian Museum of Nature, in Ottawa, flew to China to scour the Gobi for its fossilized treasures. Four major study areas were defined: the Junggar Basin in Xinjiang province in northwestern China; the Ordos Basin in south-central Inner Mongolia; northern Inner Mongolia near the Soviet border at Erenhot; and here at Bayan Manduhu, about 160 kilometres north of Linhe. The Dinosaur Project represents the first time that Western scientists have been allowed to enter Inner Mongolia since Andrews left in 1930. And we are finding hundreds of previously little-known dinosaurs.

At the lip of a deep canyon walled with red sandstone cliffs, we plunge down a narrow coulee that leads to a 70-million-year-old riverbed on the canyon floor, 45 metres below desert level. The coulee is called Nu Qi Daba, "the place where the sunshine ends." The Canadians call it simply the Gate.

The Gate opens onto one of the richest dinosaur deposits in the world. During the Late Cretaceous period, when the world's dinosaur population was virtually exploding, the Gobi was already a desert, but this canyon was the fertile floodplain of a 16-kilometre-wide river, and dinosaurs loved floodplains. Herbivores came for the lush vegetation; carnivores came for the herbivores. The Canadians have been here twice before, in 1987 and 1988. In 1988 alone, they collected 125 fossil skeletons from 49 separate quarries in three weeks. Among them were 60 rhinoceroslike *Protoceratops*; six adult ankylosaurs, heavily armoured plant eaters that grew to lengths of 5.5 metres and looked like a cross between an elephant and an armadillo; piles of teeth and claws from a carnivorous suborder called Theropoda; five kinds of dinosaur eggs; a dozen turtles; and several new fossil lizards. The most spectacular find was a pod of five baby ankylosaurs, each one about the size of a small sheep, huddled together in a single petrified sand dune about a half a kilometre north the Gate in an arid, red-walled gulch that we call North Canyon.

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This year, we have returned to find out whether there is anything more to be learned from the quarry. Including the drivers, students and technicians, there are 29 of us in camp.

In a desert, it is not the humidity, it's the heat. While not as searing as the Sahara, the Gobi's sand can still become hot enough to fry the rubber off a pair of running shoes, and I have seen beer bottles lying on their sides with their necks drooping surrealistically onto the sand, like in a Salvador Dali landscape. Now although it is barely 8 o'clock in the morning, the temperature is already 30 degrees C and the red outcrops in the distance hover above the horizon like mirages, which some of them undoubtedly are.

The dinosaurs that frequented this area 70 million years ago were hauntingly similar to those found in North America. This has been known since the 1920s, when the Andrews expedition found the first *Protoceratops*, a distant cousin of the North American *Triceratops*, and the first *Velociraptor*, an ostrich-sized carnivore that was as vicious as a ferret and so obviously close to the North American *Deinonychus* that some scientists argue they are the same genus. Ankylosaurids much like those from Inner Mongolia have been found in Alberta since the early 1900s.

If these animals were related, how did that relationship develop? Were the continents connected? Did vast herds of *Protoceratops* migrate from Asia to North America across some land bridge in the Bering Sea? Or did yet earlier forms first cross into Asia from North America and then recross after evolving into *Protoceratops*, as is known to have happened with later animals such as the wolf and the bison? Or are the similarities mere coincidences, the result of two unconnected groups of animals adapting over millions of years in response to similar environments?

We are not naive enough to expect the answers to be buried in North Canyon. Scientists do not go into the field to look for answers but to collect data. The data accumulate back in the laboratory to be analyzed, interpreted and arranged into

Dr. Phil Currie, right, and technician Kevin Aulenback, left, (both from The Royal Tyrrell Museum of Palaeontology) apply a plaster and burlap field jacket to the skull of a *Protoceratops*.

THE EX TERRA FOUNDATION/BRIAN NOBLE

theories. With dinosaurs, this can be a lengthy process. In the IVPP compound in Beijing, I saw crates of fossils that had not been examined since they were collected in the 1940s and 1950s; in the storage room of the Canadian Museum of Nature, there are specimens collected from Alberta by Charles M. Sternberg in the 1920s, still in their plaster-of-paris jackets. The questions The Dinosaur Project is asking may not be answered for decades, a sobering thought but one that fortunately does not prevent us from speculating as we go along.

The baby ankylosaur quarry has filled in substantially since 1988. Somewhat reluctantly, we take a pry bar and shovels from the vehicle, along with awls, brushes, bottles of Glyptal preservative, water bottles, sunglasses, suntan lotion, granola bars and other indispensable tools of the palaeontologist's trade, and clamber up to a sandstone slope about 30 metres above the canyon floor, halfway to desert level. Todor and I shovel while Currie, standing atop the dune and stripped down to shorts and a Tyrrell Museum baseball cap, uses the two-metre bar to break up the hard sandstone overburden. The wind blowing over the canyon seems to suck the air out of our lungs, and the sandstone walls create a kind of silica reflecting oven. After four hours, we have moved five tonnes of stone and are down to the original quarry without coming across any more bone.

"At least it's beginning to look like a quarry," says Currie. He does not seem overly disappointed; to a palaeontologist, not finding anything can be a significant discovery. Our pile of debris has grown to a mound of red sand two metres high and three metres across. Its angle of repose is very close to that of the original dune. I think about the extensions of the Great Wall that we passed this morning, higher than this and hundreds of kilometres long, and I continue digging.

Below us, crawling around on the floor of the canyon, some of the Chinese members of The Dinosaur Project are looking for fossil lizards. Their leader is Qiu Zhanxiang, the IVPP's lizard specialist. Qiu (pronounced Chew) is a very patient man. Looking for lizards is like looking for dinosaurs, except that the scale is enormously reduced: Cretaceous lizards were the size of modern

lizards. An entire skeleton can be hidden in a piece of rock the size of a walnut. Qiu and his colleagues spend hours on their hands and knees scrutinizing a few square metres of ground. Even their instruments are miniature; Qiu is using a prod that looks more like a darning needle. He does not use a magnifying glass, at least not in the desert – it is frightening to think what the sun's rays, concentrated through a lens, would do to a paper-thin lizard's rib.

Qiu and his four graduate students have spent all morning on the North Canyon floor, poring over an area of concretionary sandstone about two by three metres in size. Concretionary sandstone is harder than ordinary sandstone, and it gets griddle-hot in the sun. The temperature at head height is well over 40 degrees C; at ground level, a few centimetres from their faces, it is much hotter. Hands and knees blister first, then noses, then eyelids. Their search has not been as fruitless as ours – so far, they have collected nearly 30 specimens – but at 2 o'clock in the afternoon, Qiu straightens his back painfully and says that he thinks the site is exhausted. Just then, Li Rong, chief palaeontologist with the Inner Mongolian Museum, in Hohhot, wanders over from another site, sits on a rock to take a drink of water, looks down between his feet and sees the upper and lower jaws of a varanid, or monitor lizard, tiny teeth intact, gaping back up at him.

"We'll give it another two hours," says Qiu.

As we begin to clean up the ankylosaur quarry at the end of the day, feeling somewhat discouraged, Dong joins us. He is wearing long, baggy pants, a white T-shirt, sandals and a rumpled cloth hat. He squats beside Currie and hands over a piece of sandstone about the size of a ping-pong ball. Currie passes it around. It is surprisingly light and pebbly, like a stuccoed puffball. Dong says that he found it higher up the canyon wall, close to the lip of the desert.

"A lizard egg?" asks Currie.

Dong shrugs. "Dangerous," he says. "It could be a *Gobipteryx* egg." *Gobipteryx* is a fossil bird found by some Russians in Outer Mongolia in the 1960s. "I don't know. It may be a mammal egg. But I think it is a small theropod."

When we arrive back in camp, our cook, Tian Maolin, is using a white canvas bucket attached to a yellow polypropylene rope to draw water from a well. He pours the water into an ancient coal-fired boiler that looks like a steam engine rearing up on its haunches. The well was once part of a Buddhist temple call Hande Miao that occupied this spot for 400 years before being destroyed by the Red Guard, the militia of Chairman Mao's Cultural Revolution. The bricks were recycled to build a shepherd's commune - two long, narrow buildings with individual units opening onto the desert, like twin mom-and-pop motels in the world's most desolate vacation spot. The site was renamed Bayan Manduhu, which means "rich and plentiful."

The Mongolians still spend their summers out on the desert, following their herds of fat-backed sheep and living in yurts, and return to this compound only in winter. Because this is July, we have it mostly to ourselves. Using the end of one building as a cook shack, we trudge across the compound three times a day with our chopsticks, enamel bowls and huge, red-flowered thermos bottles, which we fill with hot water from the rampant steam engine. Then we trudge back to our rooms in the second building with our rice, boiled mutton and bottles of warm Linhe beer. We wrap the bottles in wet towels and set them out in the wind; after 20 minutes, they are almost down to room temperature.

SPECIAL EXCERPT

THE TERRIBLE LIZARD

Dinosaurs inhabited this planet for 165 million years, from about 230 million years ago to 65 million years ago. They were reptiles. They had scaly skin and ponderous tails, laid eggs and possessed a limited but evolving intelligence. And they ranged in size from the largest animals that ever lived – some grew to be 40 metres long and weighed up to 100 tonnes – to others not much larger than a modern house cat. Since 1841, when British anatomist Richard Owen first coined the word "dinosaur" (terrible lizard), more than 440 genera of dinosaurs have been discovered – about a quarter of those in the past dozen years – and new species are being found all the time. In the five years of The Dinosaur Project, its members found and described eight new species and three new genera of terrible and not-so-terrible lizards.

The Age of Dinosaurs is divided into three main periods: the Triassic, the Jurassic and the Cretaceous, each separated from the others by unexplained natural disasters – mass extinctions that are evidenced in the fossil record. The first dinosaurs appeared during the mid-Triassic. They belong to two main orders, according to the shape of the pelvis: the saurischian, or lizard-hipped dinosaurs, represented by *Herrerasaurus,* a carnivorous predator that grew to about three metres in length and about 250 kilograms in weight; and the ornithischian, or bird-hipped dinosaurs, such as *Pisanosaurus,* a small plant eater that stood on two legs and measured less than one metre in length.

The dual division persisted throughout the entire dinosaurian era, with the saurischians developing into such huge, long-necked sauropods as *Apatosaurus* (also known as *Brontosaurus)* and *Mamenchisaurus,* as well as into the seven-tonne theropod *Tyrannosaurus rex* and the tiny but no less efficient meat-eating *Troodon.* The ornithischians became the herbivorous hadrosaurs, the most common family of dinosaurs found in the Cretaceous badlands of Alberta, as well as the ankylosaurs, stegosaurs and ceratopsians also common in North America.

Although traditional palaeontology confined itself to discovering and describing new species, the "new palaeontologists" have become more interested in the biological questions raised by these discoveries. How did dinosaurs behave? Did they care for their young? Did they travel in herds? And if so, did the herds migrate vast distances north and south as their descendants, the birds, do today, or did they remain essentially stationary?

New theories about dinosaurs are coming to light almost daily. The most recent of them hold that many of the large herbivorous dinosaurs, such as the hadrosaurs and the ceratopsians, did indeed gather in huge herds, sometimes 10,000 strong, which migrated annually from summer breeding grounds in the Canadian Arctic to winter feeding grounds in the south. They appear to have followed regular migratory paths (one led right down the centre of Alberta) and to have made nests and laid eggs in the same areas year after year. The vast herds were followed by smaller opportunistic packs or predators, much as wolves follow migrating caribou herds today.

The new palaeontology is attracting scientists from many different fields: biology, palynology (the study of fossilized pollen), pathology and genetics. And the wealth of information that they are finding about dinosaurs is providing new insights into the whole process of evolution, thereby changing the way we think about life on Earth – including our own.

-W.G.

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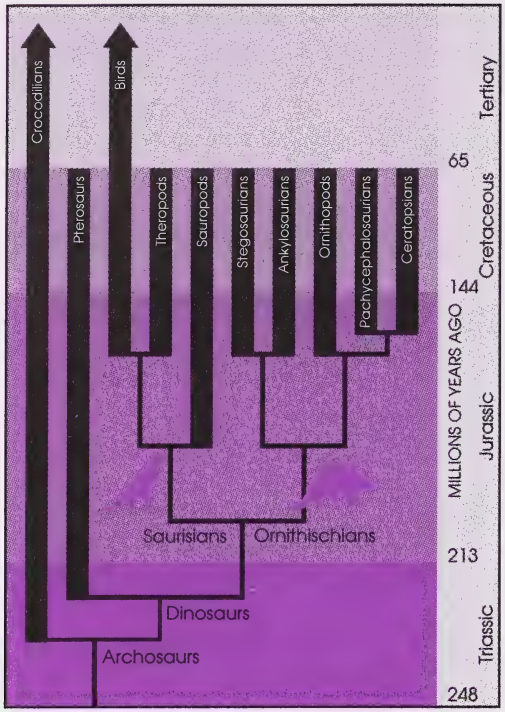
[1] *Equinox,* May/June 1992, by Wayne Grady.



In Search of THE DRAGON (continued)

Our rooms are small, with sleeping platforms that take up half the floor space, and the grimy windows and loose-fitting doors do not keep the sand from sifting through. We seal our food and cameras in plastic bags. We live three to a room, spreading our sleeping bags on the raised adobe platforms, playing cards or making notes and cataloguing specimens in the evenings until Tang Zhilu, our chief technician, turns off the gas-powered generator at 11 o'clock, and eternal silence returns to infinite space. The compound outside our rooms is strewn with broken glass slowly returning to sand. During the day, it looks like an exercise yard in a prison film, but now, at night, the moonlight reflecting off the sea of broken glass is beautiful. We have set up a volleyball net at the centre, and the huge, white moon rises over it like a perfect, ghostly service.

In the morning, we return to the ankylosaur quarry. Two years of wind and rain have reburied a sixth skull found in 1988, but after an hour of crawling over the hot sand, Currie finally finds a small, yellowish white flash of bone. We begin to pick it out with our awls, scraping at the sandstone around it, one grain at a time, and brushing away the resulting sand. The bone, though fossilized, is very delicate. Whenever a square centimetre is exposed, we stop scraping and coat it with Glyptal. Slowly, a pale skull emerges from the rock. "This is the real thrill of palaeontology," says Currie, as he works, "taking off that last layer of sand and knowing that yours are the first human eyes ever to see this animal. It's quite amazing."

The ankylosaur skull measures only about 12 centimetres across at its back – another baby – and is crushed almost flat, as if something very large had stepped on it at the time of death, although the crushing is more likely the result of aeons of pressure from its overburden of rock. When we widen the trench around it, I discover a second skull, better preserved than the first, about a metre to its right. I continue working on the first skull while Currie begins exposing more of the second. In the meantime, Todor, while clearing away rock to the left of my skull, finds a third, in even better condition than either of the first two. After two hours of shoulder-to-shoulder work, we have what looks like a miniature Mount Rushmore: three small skulls carved out of the cliff face. Over the next two days, as we remove more and more of the overburden, sometimes hacking at the cliff with our pointed hammers but more often scraping carefully at the soft stone with our awls, we find a total of seven new baby ankylosaur skeletons. We have found another pod, larger and perhaps even more important than the first one found two years ago.

That night, Currie, Brinkman, Eberth, Todor and I gather in one of the rooms to play euchre, drink a few gin and pear juices and discuss the week's finds. Brinkman is excited; he has found the skull of an adult *Protoceratops* and two fossil turtles of the genus *Basilemys*, a type that is known in both Asia and Alberta specimens, " he says, " to see how close the two are. If the Alberta species is closer to this Asian species than to other North American species, then that would argue for some connection between the two continents in the Late Cretaceous."

As he deals the cards, Currie is mulling over the significance of the second ankylosaur quarry. The animals are the same size as those in the first quarry – obviously juveniles – but whereas the first five seemed to have died clambering over one another trying to crawl out of a hole filling up with sand, these are lying beside each other, more or less at the same level, facing the same direction, with their legs drawn up beneath them as though they had died in their sleep. Eberth studied the dune composition this afternoon and says the sandstone matrix around the skeletons is composed of fine-to-medium-sized grains which, unlike the layers above and below the animals, "lack any obvious structure," suggesting that the sand was blown or fell in at the time of death, filling an area between the dunes and filling it extremely quickly. Did these seven juveniles die in the same sandstorm that smothered the five in the first pod?

The idea forming in Currie's mind is that maybe now we can begin to use the word "nest" with some confidence. Until now, theorizing that the first five baby ankylosaurs had been in a nest was, from a scientific standpoint, wild speculation. Calling something a nest implies a whole spectrum of behavioural patterns. In the case of dinosaurs, there is no solid evidence at all that adult ankylosaurs deposited their eggs in nests, like turtles, rather than distributing them singly, like geckos. And there is no evidence that once hatched, the juveniles stayed together to be nurtured by an adult, like robins, rather than immediately striking out on their own, like hatchling crocodiles. The first five baby ankylosaurs could just as easily have been caught by random chance, only coincidentally grouped together in their final moments, perhaps even washed up on some ancient shore after dying separately kilometres away. Currie felt that they were caught in a nest, but he could not prove it.

But the second find of juveniles the same age and only a few metres from the first quarry dramatically changes things. Discovering two groups of identical animals so close together greatly increases the significance of each. We can begin to develop theories about herd behaviour, nesting sites, breeding grounds. Did vast herds of ankylosaurs migrate annually along these ancient plains, stopping here to have their young? And if so, did the juveniles remain in the nests for some time?

"I think so," says Currie. "I think that when ankylosaurs were young, they stayed together in nests until they were old enough either to break away on their own or to join up with the larger herd."

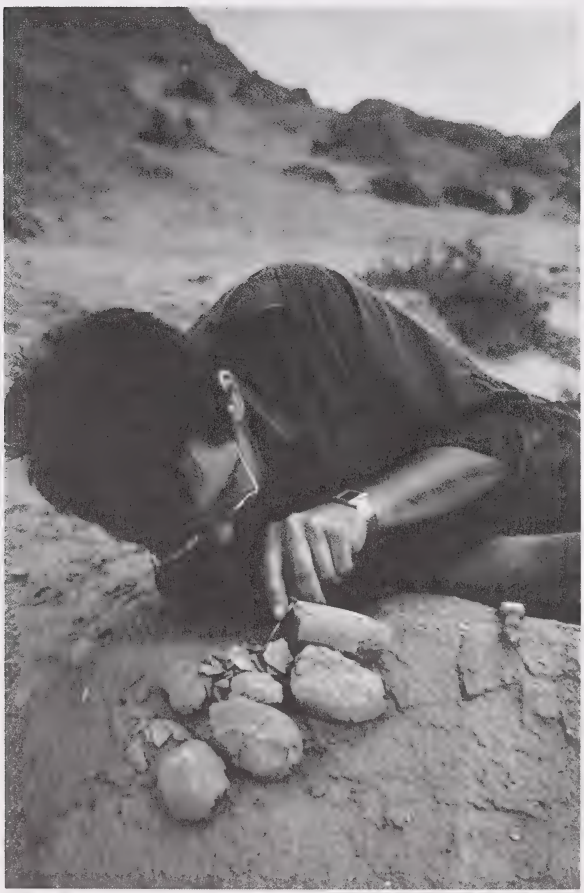
Then did the adults stay around to feed them?

"That's a tough one. The babies we've found had all the equipment they needed to forage for themselves. We found teeth in the last quarry, but they are very small teeth for herbivores. They show signs of wear, though, so they were obviously used for something. Some people think that ankylosaurs were ant eaters, but there doesn't seem to be much point to ant eaters staying together in herds, does there? There just aren't that many ants in a desert."

Dong has found a nest of dinosaur eggs at Wulan Sandan, about six kilometres from the Gate. The next morning, we drive south along the riverbed to take a look. The first dinosaur eggs known to science were discovered by Andrews in 1922 in an area he called the Flaming Cliffs, in Outer Mongolia,

about 300 kilometres from here, perhaps in the same geological formation. Andrews identified them as *Protoceratops* eggs; Currie is not sure. In fact, Andrews brought back four different types of eggs: large, oblong eggs with thick shells; smaller ones with thinner shells; even smaller ones with even thinner shells; and tiny, round ones. Andrews attributed the eggs' differences to variations within a single species – all chicken eggs are not identical, after all. But to Currie, the differences are too great, more like those between chicken and robin. There were different types of dinosaurs in Mongolia, he reasons, so why not different types of eggs as well? He suspects that the first ones, the thick-shelled, oblong variety, were, in fact, ankylosaur eggs and that the second, smaller eggs were *Protoceratops*. There is no way to tell for certain unless we find eggs with embryos preserved inside them. Dong does not think there are embryos in this nest. "No bone," he says, as we jounce along the pebbled riverbed. "Bone would be beautiful." But we are going to prospect around the nest to see what turns up.

The egg site is on a raised plateau beside the riverbed. The stone is as hard as cement. A whole day of quarrying has exposed only the tops of the eggs. They are, however, extremely beautiful – 12 ovoid shapes about 20 centimetres long arranged, ends in, in a tight circle that rises like a spiral staircase out of the ground. Dong explains that the female dinosaur laid its eggs in a hole, as turtles do, dropping them in pairs as it turned: "Two eggs dropped, turn a little, drop two more, turn a little, until the hole is full." The nest might go down 30 centimetres or more into the ground.



Dinosaur Project Technician Kevin Aulenback excavating a nest of *Protoceratops* eggs.

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"*Protoceratops*?" I ask. "Ankylosaur?"

Dong shrugs. "Dangerous," he says. I suspect that in Chinese, the word for "dangerous" is the same as the word for "hard to say." "We will study the eggs," he says, "measure them, study the rock around them, the microchemical properties of the shells, maybe take CAT scans of them to see if there are embryos inside. Until then, it is dangerous what to think."

As he and his technicians begin to gouge a half-metre-deep trench around the nest to remove the block, the rest of us prospect the area, radiating out in concentric circles. In the fluvial gravel, we find lots of small stuff – tiny fossilized claws, a sauropod tooth, small crocodile femurs – all washed down from somewhere else and thus useless for identifying the eggs.

During our usual three-hour lunch break, Currie makes a list of the specimen sites that we have discovered in North Canyon over the past month, and it comes to slightly under the 1988 count, but we still have a week to go. He is convinced that Bayan Manduhu and Bayan Dzak, the Flaming Cliffs explored by Andrews in Outer Mongolia, are virtually identical in terms of environment. "There may be some discussion as to whether they're the same formation," he says, " but the evidence is strong that the environmental conditions were the same. The fauna are the same. Andrews found about one theropod for every 60 *Protoceratops*, and we're finding the same here. He found very little sauropod material, and we're finding only a few teeth." Andrews even found a small theropod skeleton atop a nest of what he called *Protoceratops* eggs, and this afternoon, Todor found an identical site in North Canyon. "You can't get much closer," says Currie.

Eberth comes in with his ration of rice and boiled mutton and sits down on his huge leather suitcase, which contains so many rock samples that it takes two of us to lift it. Two days ago, he and one of the students, Li Yi Zhen, painted part of a cliff face with a latex compound that, when stripped off, removed half a centimetre of sand with it; it now lies rolled up in the corner of our room, waiting for someone to figure out how to get it back to Drumheller without losing its precious record of ancient Gobi desert geology. I ask him how this area compares with Alberta's Dinosaur Provincial Park.

"The Bayan Manduhu site was semiarid to arid, with seasonal rainfall and very strong winds," he says. He talks very precisely and only rarely ventures into speculation. Palaeontology may still be a soft science; geology is not. "The wind came predominantly from one direction, the southwest. I haven't found any indication of vegetation, but that doesn't mean there wasn't any. These are red sandstone beds, and they're red because the sediments have been oxidized, and oxidation destroys the organics – oxidation is burning, after all. But the water table here was close to the surface, and since the animals we are finding were herbivorous, we can assume there was some vegetation. We also know that the area was an alluvial fan spreading out into a dune field, and we know from modern examples that groundwater comes up in such areas and there is usually fairly lush growth.

"Alberta was very different. There, the climate was subtropical to warm temperate. The rainfall appears to have been seasonal too, but it was basically similar to the present east coast of Georgia or South Carolina. Dinosaur Provincial Park was the shoreline of a vast saltwater inland seaway that linked the Arctic Ocean with the Gulf of Mexico. It consisted of limited swamps, islands, estuarian channels, river mouths, a mixture of freshwater and saltwater environments. The area was tide-dominated, and the seaway was bigger than the Mediterranean and had tides as high as those in the Bay of Fundy. There were some semiarid environments and some seasonal rainfall areas farther inland, up in the rain shadow of the Rockies, but that didn't make it similar to Inner Mongolia."

If the environments were so different, why do the dinosaurs seem so alike? This is the question that nags us. Perhaps, Eberth suggests, it is really a problem of dating. "We can't date this rock by traditional methods, because it consists of grains of sand blown in from somewhere else. And since it was an isolated basin, you can't date it by the fauna, either." In other words, the dinosaurs here may have been more primitive than those in North America but

still contemporary with them, "living fossils" cut off from evolutionary processes by their isolation.

"Right now," says Eberth, "all we can say is that this area is Campanian, and Alberta is Campanian. But the Campanian covers a span of 10 million years – 75 million to 85 million years ago – and if this is Early Campanian and Alberta is Late Campanian, then the difference in climate doesn't tell us much."

"That's what I love about science," says Currie. "Every question answered raises two more."

Later that day, Zhao Xijin, Dale Russell and his two assistants, Clayton Kennedy and Kieran Shepherd, arrive in camp. They have spent the past three weeks in the Ordos Basin, a day's journey to the south. They did not have much luck – they found several psittacosaurs, two champsosaurs, a few good turtles, a pterosaur and a small crocodile skull. Russell did manage to collect data to fit his theory that China, as a continent, was isolated from the rest of the world during the Early Cretaceous and that when it linked with North America and Europe 120 million years ago, it became "a dinosaur pump" to the other continents. In a few days, we will all move on to Erenhot, but now we are celebrating with Kennedy's bottle of Glenfiddich and cans of smoked oysters, which we pick out with our chopsticks.

The door to the room is open, and sunlight streams in along the stone floor. As we talk, two Mongolian women come in. The women walk around the room as if we are not here, talking to each other in Mongolian, opening our suitcases, taking out our clothes and holding them up to the light, fingering the fabric. They pick up our books and open them, running their fingers along the lines of print. One of the women holds up my binoculars and looks at me through them, giggling. Outside, in the compound, the Chinese drivers are testing the brakes on the five-ton Jiefang truck, accelerating to top speed and then jamming on the brakes, over and over, around and around the volleyball net on which our laundry is tied.

"China," says Shepherd. "It's like living in the world's longest surrealist film."

After lunch, we return to the ankylosaur quarry. The seven baby ankylosaurs have been sculpted out of the sandstone, each skeleton sitting on its own pedestal waiting to be wrapped in gauze and plaster of paris and shipped back to Beijing. As we work, we notice the sky darkening above the lip of the canyon to the southwest. Then a roaring sound passes over our heads. The quarry begins to fill with sand. When we look down to the floor of the canyon, we cannot see it for flying sand. The air is hot and choking. We tie handkerchiefs over our noses and mouths, take ski goggles out of our packs and put them on, then make a dash in the general direction of the vehicles, which are parked up at desert level three to five kilometres away. The sand scours our bare legs, fills our ears and boots. We become separated. I find myself struggling straight up a 30-metre sand dune so soft that it feels like sugar under my feet. I take one step and slide back two, churning until I reach the top of the canyon wall and climb up onto level ground, nearly exhausted. The wind here is, if anything, worse. I lean into it and feel my way along the cliff edge. After half an hour, I reach the vehicle, nearly missing it in the storm. Currie opens the door, grins at me and offers me his water bottle.

It was in a storm such as this, I think, that seven baby ankylosaurs died under a slumping sand dune very much like the one I have just climbed.[1]

[1] *Equinox*, May/June 1992, by Wayne Grady.

9. The second paragraph of the article contains this statement: "The Gobi's geology in this area has never been properly mapped, and unless you know something about where a dinosaur skeleton comes from, finding it is useless." Why would the fossil be useless without knowing which strata it came from?

10. What was the value to each country from participating in the joint Dinosaur project?

11. The area of the dig is a hostile desert today. And the suggestion is that much of the area was also a desert at the time the fossils were laid down. What is the explanation as to why this is such a rich fossil bed?

12. What are the questions that are raised by the obviously close relationships of the fossil dinosaurs in the Gobi and their relatives in the Red Deer River valley?

13. What do you think is meant by the following statement from the article?

    "...to a palaeontologist, not finding anything can be a significant discovery."

14. a. Finding the second group of fossilized young ankylosaurs was even more significant than finding the first. Why?

    b. Because of these discoveries, what ideas about dinosaurs might need revising?

15. a. Describe the climate of the Bayan Manduhu area at the time of the dinosaurs.

    b. Compare it to Alberta's climate of that time.

16. "That's what I love about science," says Currie. "Every question answered raises two more." What does Currie mean in terms of comparing the Gobi's dinosaurs to Alberta's?

Check your answers by turning to the Appendix, Section 2: Activity 2.

"In Search of THE DRAGON" clearly shows the excitement of new discoveries – some of the excitement of the paleontologists and their field teams of unearthing new evidence after days of hard and gruelling work. Wouldn't you enjoy being a part of such discovery? Many amateur fossil buffs volunteer to work at field research sites in the summer months, along with students studying one of the many areas of paleontology. In which area would you be interested? Read the discussion of careers in paleontology on page 68 of *Visions* 2.

The paleontologist requires a Master's or Ph.D., while support positions may require a university degree or technical diploma. On-the-job training also plays a large role. In Alberta, the University of Alberta and the University of Calgary offer study in many areas of paleontology. Many other universities across Canada offer programs as well. Northern and Southern Alberta Institutes of Technology also offer some programs in the field, especially those related to sedimentology and micropaleontology related to petrology and mining.

17. If you could choose a career in paleontology, which area would you choose? What would be the positive aspects of the job? What would be the negative aspects? You may wish to contact museums and educational institutions to gather information on the career. Write a short paragraph detailing your views on the career.

Check your answers by turning to the Appendix, Section 2: Activity 2.

If you have access to the video entitled *Terrible Lizard* from the *Science Alive* series, ACCESS Network, 1993, you may watch this video for a review of how scientists at The Royal Tyrrell Museum in Drumheller work together to gather information about the fossils located in this area. The video also discusses some of the scientific principles which scientists follow when putting evidence together. You may be able to obtain this video through a local school or library.

Activity 3: Energy from the Past

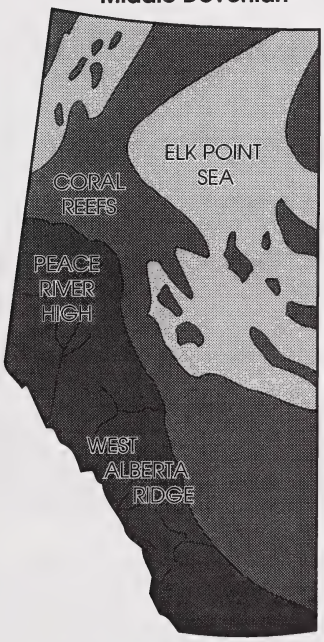
The events of the Devonian, Carboniferous, Permian, and even the Cretaceous periods have helped provide today's Albertans with thousands of jobs, low personal taxes, and one of the best economies in Canada. How could events from 400 million years ago affect us so? It was during those periods that Alberta's rich natural resources, the fossil fuels, were deposited. How were the major oil, gas, and coal deposits created? And how is knowledge from the fields of geology and paleontology used to locate these deposits?

The Formation of Fossil Fuels

Read the information beginning with the first paragraph on page 58 to page 60 of *Visions* 2. The method of petroleum formation described there, the organic theory of fossil fuel formation, does have its gaps. Scientists do not know the exact workings of chemical, biological, and radioactive processes, and heat and pressure, that would change the organic remains of sea organisms into petroleum. There are other theories. Some scientists suggest that petroleum originated in the Earth's formation and lies locked up deep in the Earth, with the pools tapped into in sedimentary layers trapping the migrating fuels. The organic theory is presently accepted, as it is fitting with explanations of development, and is leading to the tapping of Alberta's vast reserves.

In the Middle Devonian Period the sea reached into Alberta through a narrow area by today's Fort Nelson. A thin layer of sea water covered most of northern Alberta for several million years, leaving accumulated salt beds around Cold Lake and Fort Vermilion. Then the sea washed over a granite arch by Peace River, grinding it to sand which became a very porous layer in which oil such as that in the Red Earth field would accumulate. Coral reefs now became an important factor. Corals thrive at depths of approximately 25 m to 30 m. As the sea levels began to increase, corals that were growing in northeastern B.C. continued to move, building new reefs at the ideal depth and soon covered much of Alberta with living or abandoned reefs. See the map of Alberta in the Middle Devonian.

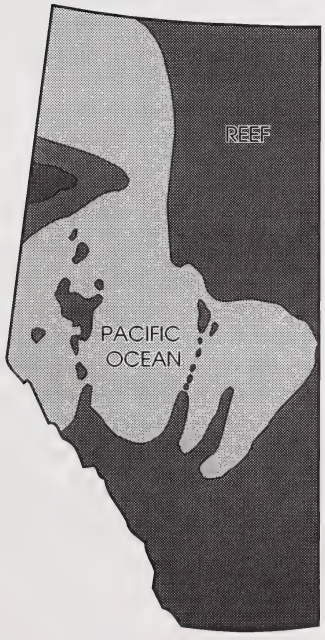
Middle Devonian



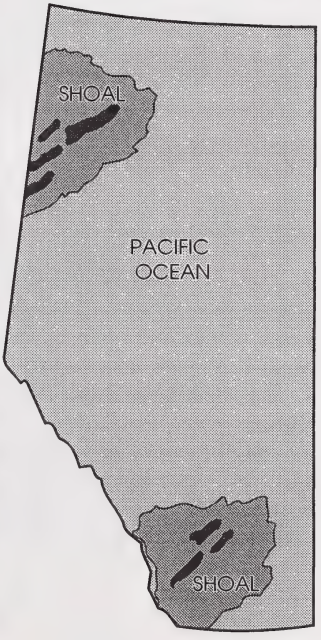
Coral reefs are significant factors in petroleum development. The reefs are one of the richest ecosystems on Earth today, supporting an incredible abundance of sea life; they were the same during the Devonian. The organisms that were deposited and changed to petroleum no doubt grew in abundance in the reefs. As the reefs moved, they left behind the "dead" reefs which collected sediments that changed into rock layers like sandstone that held the oil, or like nonporous shale that capped the oil deposits. The fossil reefs themselves are extremely porous structures in which oil and gas pooled. These fossil reef structures are searched out by geologists as ideal places to drill for oil.

Note how the seas and reefs changed in the Late Devonian, and then into the Early Carboniferous.

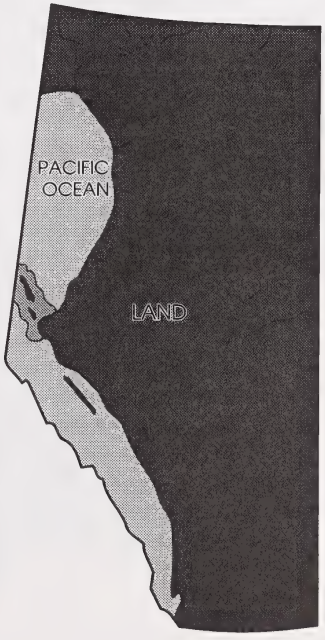
Late Devonian



Early Carboniferous



Later Carboniferous



1. Use the previous three maps to answer these questions.

   a. What can be said about the depth of the sea over most of Alberta in the Late Devonian?

   b. Describe the changes in sea level from the Late Devonian to the Later Carboniferous.

   c. Which period would likely see erosion taking place over much of Alberta?

   d. Deposits of which period would likely provide the richest sources of oil?

   e. Which period would most likely have deposited limestone, sandstone, and shale strata?

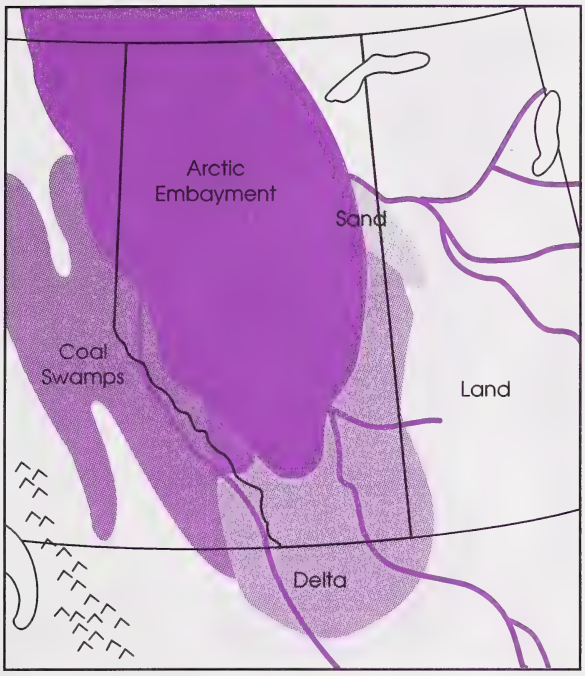
   f. Massive swamps and forests would have covered Alberta in which period?

Check your answers by turning to the Appendix, Section 2: Activity 3.

The Middle Devonian provided such oil and gas fields as those at Worsley, Swan Hills, and Judy Creek. The Late Devonian created fields such as Berland River, Pine Creek, Homeglen-Rimbey, Leduc-Woodbend, and slightly later Redwater, New Norway, Clive, Big Valley, and Drumheller. As the seas deepened and stretched into Manitoba, deposition occurred over Alberta. But as the seas retreated in the Carboniferous Period, the critical 30 m depth moved across Alberta again, this time westward, allowing new coral reefs to develop and lead to such oil and gas fields as Obed, Joffre, and Leduc-Woodbend fields.

The Cretaceous Period in Alberta

The Carboniferous Period in Europe was a time of large swamps and forests which ended up forming massive coal seams throughout most of Europe. But in western Canada, Alberta in particular, it wasn't until the Cretaceous Period, nearly 200 million years later, that the next deposits of fossil fuels were being laid down. Refer to the map that follows as you read the remainder of this paragraph and the next paragraph. The tar sands at Fort McMurray developed during this time, probably developing its tarry oil from two sources. As the streams of those days flowed northward and westward to the encroaching Arctic Embayment, they eroded into many Paleozoic coral reef oil pools, carrying the oil to collect in the sands at the edge of the embayment. As the Arctic sea waters moved southward, the decomposing bodies of trillions of minute organisms were deposited in mud overlying the sands. Later pressures squeezed out the tarry substance to collect in the sands.



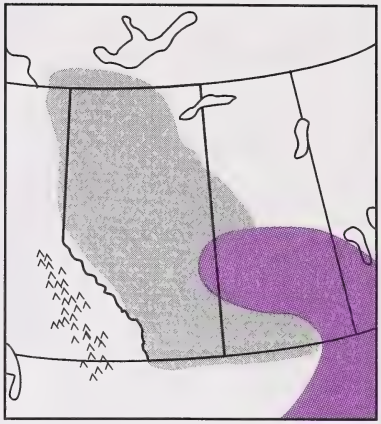
At the same time, vast coal-forming swamps thrived along the western edge of the sea, laying down some of the valuable coal deposits mined today in the Crowsnest and Grande Cache areas. Most of the forests were made up of conifers, cycads, ferns, and gingkos. These plants accumulated in the swampy areas, being prevented from rotting by being "pickled" by humic acids in the brown-coloured stagnant waters. When the layer of vegetation is thick and becomes buried, the moisture is squeezed out, the volatile fluids are lost, and the carbon is concentrated. Over the ages the coal changes from brown to black.

In the Late Cretaceous, Alberta was again covered by a sea that stretched from the Arctic to the Gulf of Mexico as shown in the following map. One of the province's largest oil fields is found in a sand body laid down in this sea. The Pembina oil field covers about 140 000 hectares beginning under 1800 m of rock cover at the west and rising until pinched out in the east by deep-water clays, now impermeable shales.

At the very end of the Cretaceous the seas again retreated, leaving a huge delta over most of the province. This delta is shown on the map labelled Late Cretaceous. The Belly River Delta was a rich swampy area that supported a huge coal-forming forest and was home to a wide variety of animals, the most famous of which are many of the dinosaurs found in the Red Deer River valley. The coal beds of the Edmonton district, the Drumheller valley, and the outer foothills are from this time.

Late Cretaceous

End of Cretaceous



Petroleum Traps and Reservoirs

How does petroleum laid down throughout a strata accumulate so that it is in pools large enough to warrant the cost of drilling a well to recover it? Much depends on the behaviour of oil and gas.

Science Skills

- ☐ A. Initiating
- ☑ B. Collecting
- ☑ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Investigation: Behaviour of Oil and Gas

Follow the directions of this investigation carefully. Pay special attention to the required components, safety aspects, and applied science skills.

Purpose

Examine how oil, gas, and water behave when mixed in materials of differing porosity.

Materials

- 2 clear, similar-sized, glass jars with lids (about 1 L)
- 1 glass jar with lid (0.5 L to 1 L) for mixing oil and coloured water
- 1 glass jar (0.5 L to 1 L) to hold coloured water
- measuring cup
- 1 cup of clean, fine sand
- 1 cup of glass beads, extremely coarse sand, or very small pebbles
- 1 cup of liquid salad or cooking oil
- 1 cup of water
- food colouring

Procedure

Step 1: Place the sand in one jar and the coarse material in the other. (Use the similar-sized jars here.)

Step 2: Measure one cup of water into a small jar and colour the water with the food colouring.

Step 3: Mix one-half cup of the coloured water and one-half cup of oil into another small jar. Shake or stir vigorously.

Step 4: Pour the mixture into the jar with the sand. Place the lid on the jar and shake up the entire mixture. If you don't have jars with lids, you may just stir the oil-water mixture into the sand and cover the jar with plastic wrap or some other material so water cannot evaporate.

Step 5: Repeat Steps 3 and 4 with the jar of coarse material.

Step 6: Set the jars in a location where they will not be disturbed.

Step 7: Observe the jars after five minutes, thirty minutes, one hour, five hours, one day, and three days.

Step 8: Make a chart like that in the Observations section.

Observations

Observe the movement of the water and oil in the two jars as described in Step 7 of the Procedure, and record your observations in a chart like the following. Measure and record the thickness of each layer at each time interval in both jars to the nearest tenth of a centimetre.

2. Draw a chart like the one that follows and enter what you observed in each jar.

Time	Jar with Fine Sand	Jar with Coarse Material
5 minutes		
30 minutes		
1 hour		
5 hours		
1 day		
3 days		

3. Compare what occurred in each jar at five minutes, thirty minutes, one hour, five hours, one day, and three days.

4. Draw the layers observed in both jars. Compare the final positions of air, oil, and water in the two jars.

Analysis and Interpretation

5. If the air in the jar compares to natural gas, the salad oil to oil, and the water to underground water, in what order would natural gas, oil, and water in nature arrange themselves?

6. The approximate specific densities of natural gas, oil, and water are 1.00, 0.67, and 0.92, in random order.

   a. Match each material to its specific density.

      1.00 – _____
      0.67 – _____
      0.92 – _____

   b. Explain how you deduced the specific density relationship based solely on results recorded in the Observations.

7. Which of the materials (fine sand or coarse material) exhibits the most porosity? Explain how this investigation shows that.

8. Carefully pour the water and oil out of the jar containing the coarse material, leaving all the beads or pebbles in the jar. Measure the amount of oil and water. Quickly but carefully pour the water and oil out of the jar with the fine sand, leaving all the sand in the jar. Measure the amount of oil and water.

   a. Which material released the most water and oil?

   b. The amount of oil and water started out equal. Why did the one jar release less oil and water? Where is that oil and water?

   c. What does this show about the movement of liquids through materials of differing porosity?

9. Consider two petroleum reservoirs, each containing the same amount and type of natural gas and oil. One reservoir has the petroleum trapped in rock strata of fine sandstone. The other has the petroleum trapped in rock strata of very coarse sandstone. Which reservoir would an oil company most likely choose to drill in? Explain why.

10. Arrange these materials in order based on the quickness with which these materials will allow liquid to move through them.

- granite
- shale
- sand
- gravel
- sandstone
- slate
- limestone

Check your answers by turning to the Appendix, Section 2: Activity 3.

Your investigation showed you that oil, water, and gas can migrate through some types of rocks. The source rock in which the original organisms were laid down is often not the reservoir rock in which oil pools are found. Usually the organisms collected on the silt and clay on the ocean floor. As these deposits were buried and compressed, the clays and silts changed to shales, a porous rock that is very **impermeable**. Oil does not flow easily through shale, but the pressures of overlying rock squeeze the oil out of it, with the oil usually moving laterally between the thin "layers" of the shale until it reaches a suitable reservoir rock. Reservoir rock is a porous rock, easily permeable, such as sandstone, limestones, dolomites, and fossilized coral reefs (which may sometimes be the source rocks as well). The fossil fuels can pool and move through these rocks with varying degrees of ease. Porosity, the percentage of void space in a rock, varies greatly among the rocks. But what stops the petroleum from continuing its movement? It meets an impermeable rock strata, most often a shale, but sometimes a solid limestone.

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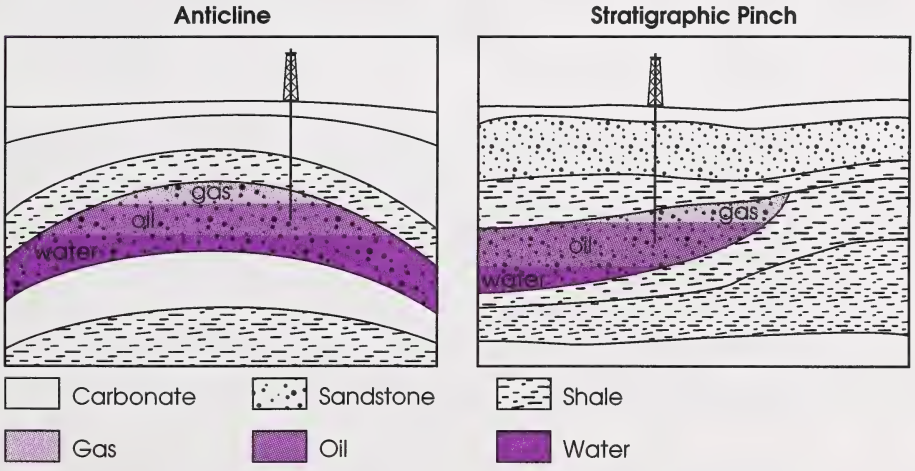
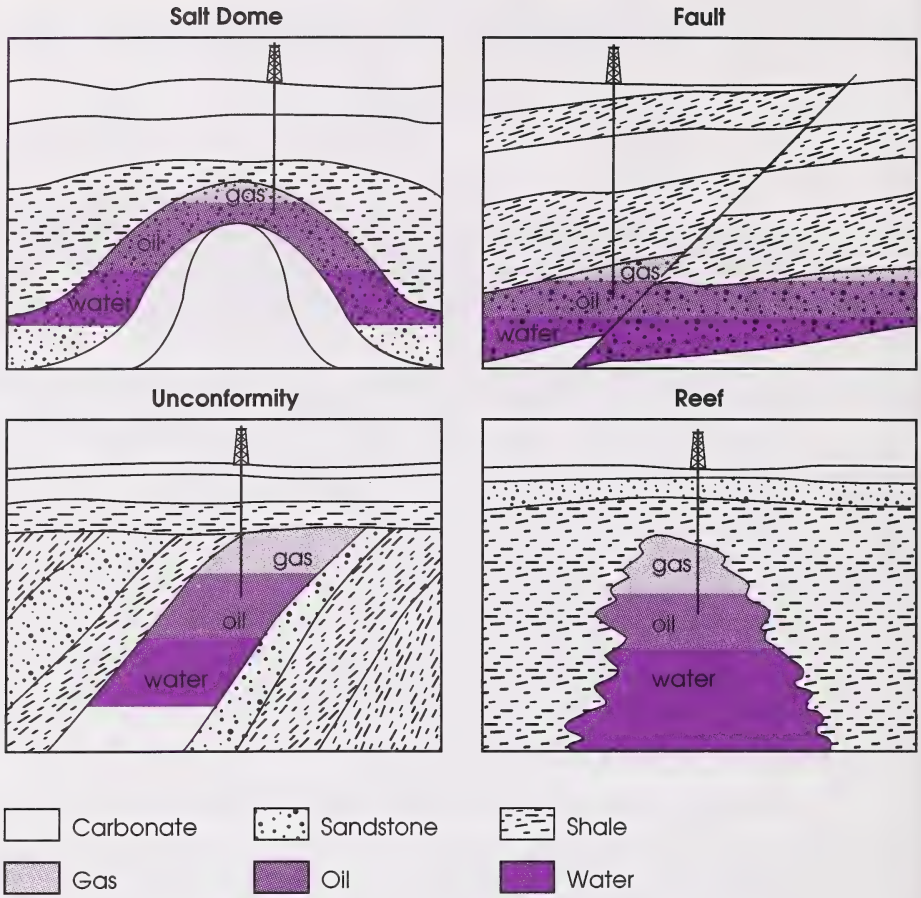
These trap structures take a variety of forms as illustrated in the following diagrams.

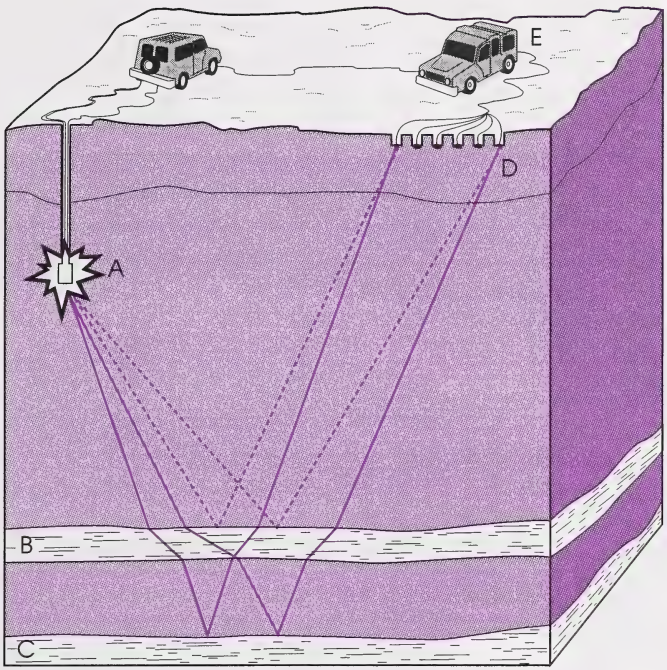




The Search for Oil

How do oil companies use this knowledge of stratigraphy and paleontology in their search for oil? They use many different techniques to lead them to likely oil-bearing formations. At this time more than 4 000 000 core samples have been drilled across North America. These core samples allow geologists to measure the thicknesses of rock strata and determine their make-ups. They can be analysed for porosity, fossil content, and traces of petroleum, metal ores, or gemstones. This information is added to the huge quantities of geological and paleontological data already recorded about most areas of North America. The geologists study all this data, searching for likely strata and formations that will be worth exploring further. Then seismic crews may be sent to gather information about particular likely areas.

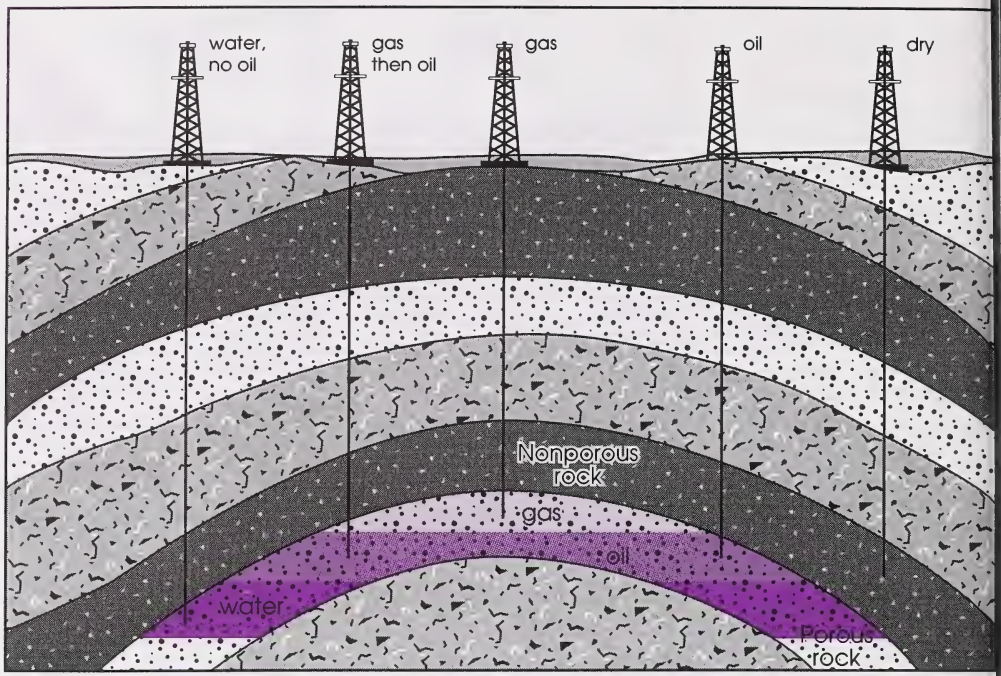
Seismic crews spread out sensitive monitoring devices and then set off explosions or vibrations that send shock waves down into the ground. The shock waves are timed as they travel down to underground rock strata, bounce off each layer, and return to the surface monitors. The speed of return indicates the depth and nature of the rocks below See the diagram which follows



Today most seismic data is recorded electronically and taken back to sophisticated computers that produce the images revealed by the seismic waves. Other test results may also be added. Acoustic properties, differences in gravitational pull, differences in magnetism, and variations in resistance to electrical current are other types of data that may be used. But these methods still only hint at what is really underground. The geologists study the information revealed by the seismic data and find the specific formations that are linked to the presence of oil – the traps, relationships of porous to non-porous strata, and so on.

Then sample cores are often dug to give further hints if they are on the right track. Core samples allow the geologists to determine the exact porosities of the strata. Shale usually has a porosity of less than five percent, making it a good cap rock. Sandstone has a porosity of more than ten percent, and for oil companies, the more porous the better in oil-producing rock. If a reservoir rock layer has a porosity of eight percent, an oil company can make money, but the higher the porosity, the more quickly the petroleum can flow through the rock to the well. The geologists also examine the core samples from each well dug for the fossils present on the material. This helps them identify particular oil-bearing strata. For instance, some fossils might mark a particular strata as being a Late Devonian sandstone. The geologist knows that this is often an oil rich strata. Fossilized coral might suggest a fossilized reef, linked to rich, easily tapped oil deposits.

Drilling a well can cost millions of dollars, so the geologists try to pinpoint within a few dozen metres the best location. Look at the following diagram that shows how easy it is to drill a dry hole.



Use Figure 2.9 to answer questions 11 to 18.

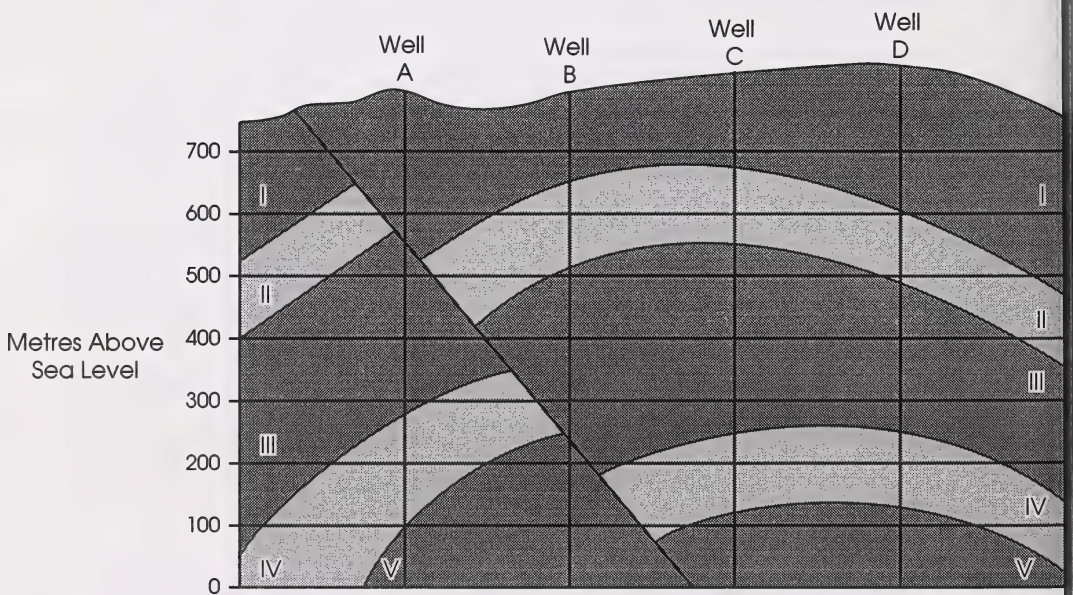


FIGURE 2.9 Possible Drill Holes Through Various Strata

11. Study the information in Figure 2.9 and use it to complete the following chart. You will fill in the information for Well C and Well D that tells when each well reaches a particular rock layer. The measurements are given in metres above sea level.

Layer of Strata	Porosity	Well A	Well B	Well C	Well D
I: shale	3%	surface	surface		
II: sandstone	15%	absent	650		
III: shale	3%	550	510		
IV: sandstone	12%	275	absent		
V: shale	3%	100	225		

12. Which will be the most likely well to hit oil or gas? Why?

13. What two trap formations are present in this diagram?

14. a. The sandstones in Layers II and IV contain oil and gas. In terms of oil formations, what would those strata be called?

    b. The shales in Layers I and III are impermeable. In terms of oil formations, what are these layers called?

15. Well C hit natural gas in Layer II. Well B hit oil in Layer II. Well D hit water in the same layer.

    a. Explain how that is possible. You may need to refer to the illustrations about types of traps and reservoirs earlier in this activity.

    b. Illustrate the situation by drawing how the gas, oil, and water must be located in Layer II.

16. Although Layer IV is oil-bearing rock, Well A hit only water. Explain how that is possible.

17. Which well will most likely be the best producer of natural gas? Explain.

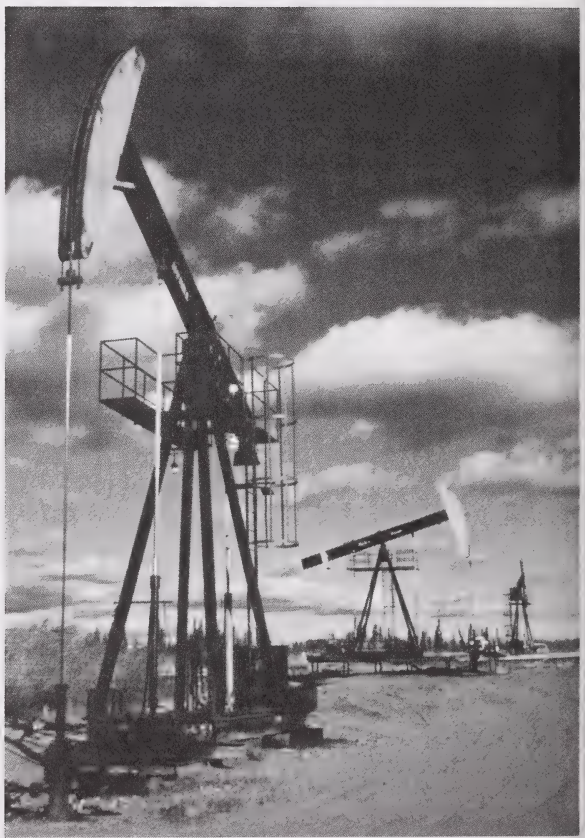
18. Which well will most likely be the best producer of oil? Explain.

Check your answers by turning to the Appendix, Section 2: Activity 3.

Fossil Fuels in Alberta Today

Alberta's coal resources are immense, estimated at 2 600 000 000 000 tonnes, with 800 000 000 000 tonnes considered recoverable. Eleven major mining locations produced 32 500 000 tonnes of coal in the 1991 calendar year. The increase over previous years is due to more coal being used to feed the province's electrical generating plants. There is enough coal in Alberta to provide energy for these plants for 1100 years. Alberta today supplies forty-one percent of Canada's total coal production. Seventy-one percent is used for production of electricity while twenty-three percent is exported. Revenue to the province from coal royalties totalled $26 400 000 in the 1991-92 fiscal year.

Crude oil continues to be a major player in the Alberta economy. In 1991, 327 million barrels of conventional crude oil were produced, netting royalties of $1 000 000 000. The remaining established reserves of conventional crude oil that can be retrieved with current technology totalled 2.9 billion barrels at the end of 1991, which would last nine years at current production levels. New reserves, however, will be located, and new technologies may make more oil recoverable, so the Energy Resources Conservation Board estimates 6.6 billion barrels as the ultimate potential. The reduction in conventional reserves is spurring efforts to find new methods of coaxing additional oil out of depleted reservoirs. This **enhanced oil recovery** (EOR) ensures that the maximum amount of crude is recovered from reservoirs by injecting water or gas into the formation to force the oil out of the rock. A new method of EOR receiving increased attention is the injection of a solvent such as ethane, propane, or carbon dioxide to flush the oil from the small pore spaces in the rock.



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19. Calculate how long the estimate of ultimate potential reserves will last at current production levels.

Check your answers by turning to the Appendix, Section 2: Activity 3.

Non-conventional oil (synthetic crude and bitumen) totalled $30 600 000 in revenues in 1991-92. Syncrude produced 60 million barrels, Suncor 22 million barrels, and crude bitumen production was 45 million barrels in 1990. Syncrude and Suncor extract bitumen from the oil sands around Fort McMurray by mining the sands, treating the sand with steam and chemicals to remove the bitumen, and upgrading the bitumen into synthetic crude oil. Ultimate recoverable reserves of bitumen are estimated at 300 billion barrels, which represents only about twenty-five percent of the total oil sands resource. The remainder will require new techniques in order to be recovered. **In situ** is the other basic recovery method for oil sands deposits. In in situ projects, the bitumen is removed from the sands while it is in the ground. The heavy oil is heated in place to increase its viscosity so it can be pumped to the surface. Esso's Cold Lake project is an example of in situ recovery. In terms of geological potential, almost ninety percent of Canada's total remaining unexploited oil resources are estimated to be bitumen from Alberta's oil sands.

As oil prices have remained soft, natural gas exports have become more important in contributing to the revenue of the provincial government. In 1991 natural gas production was 3.3 trillion cubic feet from more than 18 000 known gas reservoirs, with exports totalling 1.45 trillion cubic feet. In the 1991-92 fiscal year, natural gas contributed $840 000 000 to the province. At the end of 1991, the remaining established reserves totalled 58 trillion cubic feet, which would last 17.5 years at current production rates. The Energy Resources Conservation Board estimates reserves of 107 trillion cubic feet will be available with improved discovery and production techniques.

As you can see from the figures provided, Alberta is fortunate in its energy wealth, but you can also see that the reserves are limited. Note how a common theme throughout that information was new recovery techniques and improved techniques. In 1991-92 the energy industry contributed more than $2 300 000 000 to the provincial coffers. But the economic contribution went far beyond that. Tens of thousands of people, from geologists to secretaries to exploration crews, are employed directly by the energy-producing companies. Money is spent around the province to spin-off companies. Suppliers, machinist shops, equipment, truck dealerships, restaurants and motels, and so on. The list of beneficiaries from the energy industry is amazing.

Perhaps the oil or mining industry interests you as providing a prospective career. There is a wealth of professional, white collar, and blue collar jobs associated with these industries. Check out Alberta's universities for degree programs in geology and engineering. And look to institutes of technology for programs in petroleum technology.

20. Coal was very important in the 1800s, as it fuelled the industrial revolution, through to the 1940s.

    a. What caused the decline in the importance of coal as a fuel?

    b. What has caused the resurgence in importance of coal as a player in the energy industry in Alberta?

c. What do you see as the future of coal as an energy source in Alberta?

21. Oil and gas revenues paid to the province have dropped in the early 1990s and compared to the early 1980s. What do you see as the longterm future of these revenues? Explain.

22. Where does Alberta's energy future lie – in coal, conventional oil, synthetic crude oil, or natural gas? Explain.

23. Use your imagination to come up with solutions to these problems energy companies must solve in the future. Maybe you will come up with a multimillion dollar process.

    a. What is a possible new process to discover previously hidden oil and gas reservoirs?

    b. What is a possible new process to help recover more conventional oil from depleted reserves, or more bitumen from in situ wells?

Check your answers by turning to the Appendix, Section 2: Activity 3.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

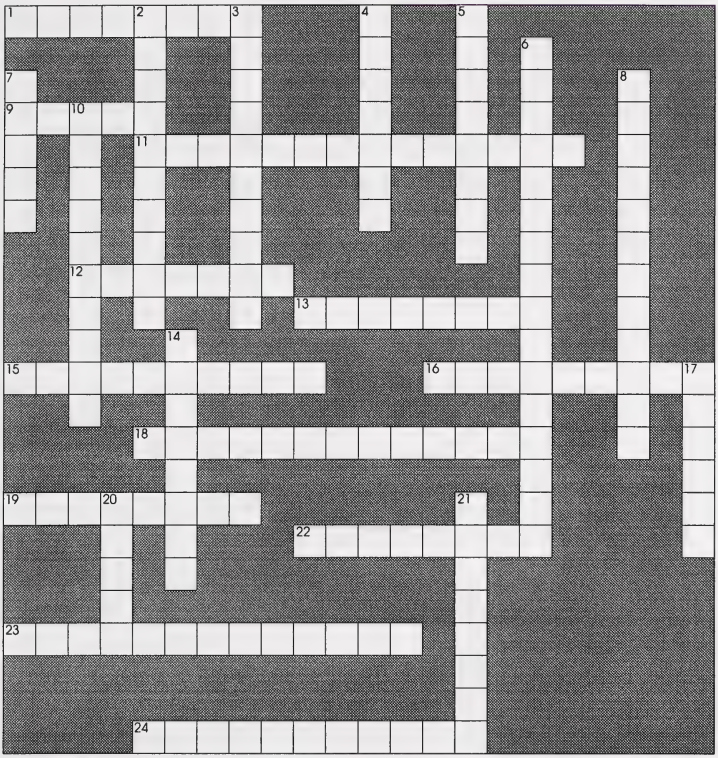
Extra Help

Paleontology

VISIONS

Most of Activity 1 covers the geological column and the fossil record, putting it into logical order by using charts and tables to organize geological time and the fossils and strata created throughout time. Study Table E.3 on pages 554 to 556 and Plate 2.1 on page P-3 of *Visions 2*.

1. Complete the crossword that follows, using terms covered in Activity 1.



Across

1. an era that began 245 million years ago, best known for its reptiles – dinosaurs

9. a layer in the atmosphere that protects plants and animals from ultraviolet rays

11. tiny, single-celled organisms drifting in the sea and forming limy shells, markers for strata 65 million years to present

12. extremely rare element found between strata of the Cretaceous and Tertiary Periods, most commonly found in meteorites

13. an era known as "Time of Recent Life," divided into two periods with seven epochs

15. This and the Tertiary periods make up the Cenozoic Era.

16. an era that began 570 million years ago with the appearance of the first vertebrates

18. a period noted for worldwide coal deposition

19. the most well-known period for dinosaurs; first fossil birds, Archaeopteryx, appeared

22. a period noted for major corals, arthropods, spiders, amphibians, and especially fish; very important for the development of Alberta's oil and gas reserves

23. a scientist who studies fossil plants

24. an era of geological time stretching from the creation of the Earth to approximately 570 million years ago, when first life appeared

Down

2. remains of ancient life that are best if extremely plentiful, spread around the globe, well-preserved, and stretching across short periods of geological time (two words)

3. a period of major rock deposition lasting 70 million years, with its end marked by the extinction of the dinosaurs

4. period marked by the appearance of therapsids, mammal-like reptiles, probably the ancestors to later mammals

5. a period correlated by trilobites worldwide

6. a principle based on the idea of increasingly complex life-forms correlating with increasingly newer rock strata (two words)

7. animal which lives in close symbiotic relationship with algae in sea water between 25°C and 29°C; helps map locations of ancient seas

8. study of ancient life-forms

10. a period beginning approximately 505 million years ago; possibly the first plants on land occurred

14. first period of the Mesozoic Era; first true mammal fossils found late in the period

17. geological _____, a complete recording of oldest rock strata to newest

20. blue-green _____, one of the Earth's earliest life-forms

21. a period beginning nearly 438 million years ago; possibly first terrestrial animal life occurs

Check your answers by turning to the Appendix, Section 2: Extra Help.

Paleontologists

Paleontologists are scientists that study ancient life through the remains left in the fossil record. The Royal Tyrrell Museum of Palaeontology plays a key role in the study of Alberta's rich fossil beds and in research projects around the world, such as the Dinosaur Project in China. This project in the Gobi Desert showcased the similarities between the dinosaurs there and the same species found in Alberta's badlands. Two "nests" of baby ankylosaurs raise questions about whether the dinosaurs functioned in herds and whether they raised their young in a caring fashion.

Fossil Fuels

Perhaps the most valuable fossil remains found in Alberta are the fossil fuels. Coal, oil, and natural gas are called fossil fuels because they are the fossilized remains of plants and animals that have been transformed through heat and pressure into today's fuels. Coal was formed when layers upon layers of swamp ferns and other plants were deposited under the swamp water. Swamp water contains very little oxygen, so the wood did not rot, but collected in thick layers which were then covered by deposits of sand or clay. Through compression, the carbon in the wood was concentrated to form coal as found today in deposits around the province.

Oil and natural gas were formed when small sea animals collected in layers on the sea bottom and were covered with sand, clay, and silt. Layer upon layer was deposited around the rich coral reefs in the warm tropical seas that covered Alberta at that time, especially in the Devonian and Cretaceous periods. Heat, pressure, and perhaps chemical and biological forces acted on the organic sediments and changed them to fossil fuels. The natural gas, the oil, and frequently water, collect in porous reservoir rock strata like sandstone. A nonporous cap rock, like shale, confines the liquids, causing them to pool in traps like those described in Activity 3.

2. a. Draw two types of reservoir traps and label each type.

   b. Draw in and label natural gas, oil, and water layers in each reservoir.

   c. Draw a well, that when drilled into the first reservoir, would hit oil first.

   d. Draw a well, that when drilled into the second reservoir, would hit gas, then oil, then water.

Check your answers by turning to the Appendix, Section 2: Extra Help.

Enrichment

1. Do a more detailed study of the complete geological column of Alberta. You may want to focus in on the geological characteristics that make Alberta a fossil-rich province. Use resources such as those listed in Activity 2.

2. If you have access to the video, *Petroleum: River of Energy*, ACCESS Network, view it for an interesting look at the petroleum industry across Canada from exploration to refining. This video was produced by the Petroleum Resources Communication Foundation. You may be able to obtain this video through a local school or library.

3. Coal is one of the fossil fuels that rarely makes the news like the oil and gas. It is, however, very important for electrical generating and for export. You may wish to research the major coal fields of Alberta, discovery and mining techniques, and so on.

4. In 1992 and 1993 large areas of Alberta were leased to companies for diamond exploration. Upon what evidence were these leases filed? What exploration has been done? Do you think Alberta will become a major diamond producer? You may find information to explore these questions in magazine and newspaper articles of the last couple of years.

Check your answers by turning to the Appendix, Section 2: Enrichment.

Conclusion

In this section you have examined the rich and interesting prehistory of Alberta. The study of paleontology reveals the relationships between the geologic events in Alberta's distant past and the fossil plants and animals laid down in our rock strata. Much of Alberta's prosperity depends upon knowledge of the geologic past. The Royal Tyrrell Museum of Palaeontology brings this past alive for the huge numbers of tourists who visit Drumheller and Dinosaur Provincial Park every year. The museum's scientists participate as respected members in scientific projects both in Alberta and internationally. Alberta's geologic history has also provided valuable natural resources. The production of coal, oil, and natural gas has helped Alberta's economy by providing jobs, giving relatively cheap energy and contributing royalty monies to the government. Further study on your part could open the door to many careers in scientific research and the natural resource industries.

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 2.

ection

3 Theories of Evolution

WESTFILE INC.

WESTFILE INC.

The Earth – once a ball of molten material moving through the abyss of space. Today, home to a thriving ecosystem diverse with millions of plants and animals in the sea and on land. What are the processes and mechanisms that took that lifeless, inhospitable early Earth and developed it into home for humanity and the flora and fauna upon which it depends?

In this course, you have already learned much about the formation of the Earth, its tectonic plates, development of continents, and its rock layers. Then you studied stratigraphy and how the fossil record is used to correlate strata worldwide. The key to that study is the principle of faunal succession which introduces the theories of evolution you will examine in this section.

You will examine the development of early ideas about evolution and then Charles Darwin and his introduction of the theory of gradual evolution. You will also examine the more recent punctuated equilibrium theory of evolution. You will evaluate the theories of evolution in order to examine their strengths and weaknesses in explaining the development of life on this planet.

Activity 1: Once Upon a Time...

When the Earth was first formed, there was virtually no atmosphere. How is it that the atmosphere as you know it today evolved from that early inhospitable situation?

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☑ C. Organizing
- ☐ D. Analysing
- ☐ E. Synthesizing
- ☐ F. Evaluating

1. A number of possibilities in the evolution of the atmosphere are presented in the following statements. All are likely events that did contribute to the atmosphere's development. Use your knowledge of paleontology, the geologic column, and evolution to arrange the events into chronological order. Number the events. Two events are numbered for you.

10 a. Plants increase rapidly in the seas, releasing large quantities of oxygen, and begin to move on to the land.

_____ b. Algal plants begin producing enough oxygen so that free oxygen begins to accumulate.

_____ c. Organic compounds would not have been oxidized and were available as nutrients for bacteria-like procaryotic cells.

_____ d. Animals develop and increase in size, up to 5 cm to 10 cm long, for the atmosphere is now oxygen-rich, approximately 10% of today's amount.

1 e. At the very high temperatures of the young Earth, the force of gravity is not strong enough to hold an atmosphere.

_____ f. Basic modern atmosphere is present, subject to some fluctuations in carbon dioxide and oxygen.

_____ g. Ozone layer begins to develop, preventing harmful ultraviolet rays from reaching the Earth's surface, and creating a safer environment for life near the sea surfaces and on land.

_____ h. Carbon dioxide increases dramatically, leading to global warming.

_____ i. First shallow seas develop, creating ideal habitat for other algae to develop.

_____ j. Intense volcanic activity releases nitrogen, carbon dioxide, water, hydrogen, hydrogen chlorides, carbon monoxide, and small amounts of oxygen to create an atmosphere.

_____ k. Oxidation of materials begins, staining sedimentary rocks red from oxidized iron.

_____ l. Modern plant and animal families develop.

_____ m. Ozone layer is reduced due to chemical destruction.

_____ n. First photosynthesizers, blue-green algae, begin releasing oxygen into the atmosphere.

Check your answers by turning to the Appendix, Section 3: Activity 1.

Read from page 80 down to and including Figure 3.1 on page 83 of your textbook. You can see from this reading that evolution of the atmosphere went hand-in-hand with the development of life on Earth. The atmosphere had to develop to certain conditions in order for first life to begin; then, once photosynthesis began in organisms, the atmosphere began to be modified by the life-forms, especially green plants. Of course, the development of the atmosphere and life on Earth are also parts of the grand system of global processes such as the movement of tectonic plates, the rock cycle, hydrologic cycle, and so on. All processes are interrelated and affect each other.

2. Explain how the first element or process affects the second in each of the following phrases. You may need to discuss the interrelationships of the two.

   a. sun on development of the atmosphere

   b. sun on the development of life on Earth

   c. movement of tectonic plates on the rock cycle

   d. movement of tectonic plates on the development of the atmosphere

   e. atmosphere on the development of life

   f. life on development of atmosphere

   g. movement of tectonic plates on the development of life-forms

3. What human actions are now creating changes in the Earth's atmosphere?

Check your answers by turning to the Appendix, Section 3: Activity 1.

Read the following article from the November 25, 1993 edition of *The Edmonton Journal*. Note especially the interrelationships of plants, climate, and atmosphere shown in the article.

Cold snap wiped out beech trees

Mini-ice age gives scientists insight into how trees affect climate

Allen Panzeri
Journal Staff Writer
Edmonton

It was only a slight temperature decrease – two degrees at the most.

But it devastated southern Ontario's forests, likely contributed to global warming, and, ironically, led to one of early Canada's largest economic bases, according to Edmonton scientist Ian Campbell.

It was also a temperature decrease that will likely provide valuable insights into forest management and into the complex relationship between trees and global warming.

In a paper to be published today in the prestigious scientific journal *Nature*, Campbell, a research scientist with Forestry Canada, and John McAndrews of the Royal Ontario Museum, conclude that the temperature decrease during the Little Ice Age from 1450 to 1850 was largely responsible for wiping out the once-dominant beech tree in southern Ontario.

The beech, a slow-growing tree that doesn't need a lot of light, was at the edge of its climactic tolerance zone. When the temperature dropped, it died off, supplanted by faster-growing and heartier birch, oak, and white pine.

"It just got too cold and the beech couldn't adapt," said Campbell.

Usually, forests replenish themselves in an orderly way: one tree dies, another grows to take its place. But this time entire forests disappeared.

"Even though 400 years seems like a lot in human terms, it is really only a generation in tree terms," said Campbell.

"To put it in perspective, it was a catastrophe for the forest."

There was one benefit, though.

The establishment of white pine, which has continued to increase its presence, became one of the most valuable commodities to the English colonists who had begun to arrive in Canada.

With tongue only slightly in cheek, Campbell says the "course of Canadian history may well have been determined" by the rise of Ontario's pine forests.

However, the demise of so many beech trees at once, and the potential the same could happen again anywhere during a climactic change, is a big problem, because it contributes to global warming.

Because oak, birch, and pine grow less densely than beech, Campbell and McAndrews estimate the total weight of living matter in the southern Ontario forest decreased by about 33 per cent over a few hundred years.

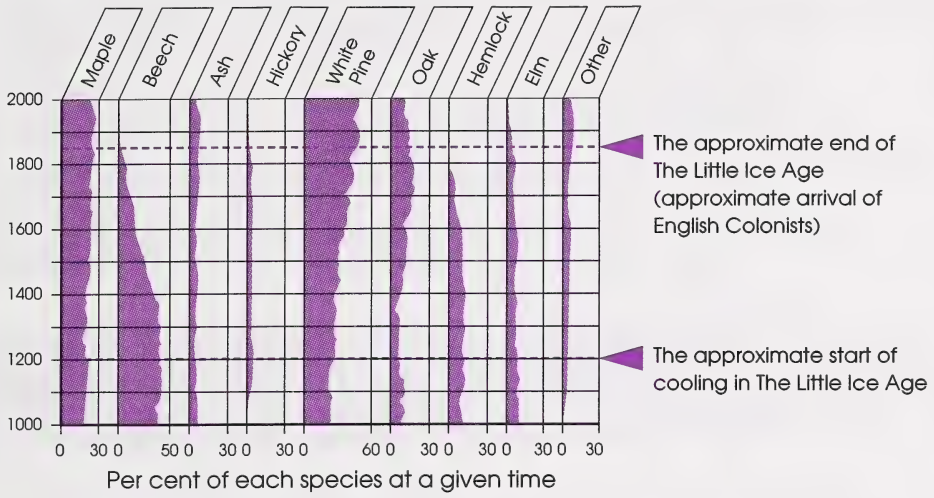
This means there was less carbon actually stored in the forest and more that had been released into the atmosphere as carbon dioxide from rotting or burning beech trees.

Carbon dioxide is one of the main greenhouse gases that allow the planet's surface to be maintained at a habitable temperature. But scientists warn that if the concentration of these gases increase, they will intensify the effect and cause global temperatures to rise dramatically.

That, in turn, will lead to a dramatic impact on forests all over.

Campbell is quick to point out he's not an alarmist and that a lot more research is

Computer simulation of the history of Southern Ontario's forests from the year 1000-2000



needed.

"What we're saying is that there's the potential for forests to play a greater role in climactic change than we previously thought."

One day, the research may even influence the way forests are harvested.

Dead and dying trees would be culled, to prevent them from simply rotting or burning and releasing carbon dioxide. And new trees would be planted only well within their climactic zones.

"Trees are still organisms and like every organism, they have their limits," said Campbell.

"We don't see that because they're very tolerant of things we aren't tolerant of, and because our time frame is not theirs.

"But this shows that forests can be vastly more sensitive than we thought and can respond really quite dramatically to minor changes in temperature."[1]

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

4. What do you think could have been the causes of the Little Ice Age?

5. a. Explain how the climate change of the Little Ice Age affected the forests of southern Ontario.

   b. How did the change in the forest affect the atmosphere?

   c. Explain how the change in the atmosphere most likely affected the climate.

   d. In turn, how will the change in the climate likely affect the forest?

   e. What human endeavours does this article show were affected by these climate changes?

The Edmonton Journal for the article "Cold snap wiped out beech trees," by Allen Panzeri, November 25, 1993. Reprinted by the permission of *The Edmonton Journal*.

6. What does this article suggest could be the results of humans destroying the world's rain forests?

7. What would be the purpose of culling dead and dying trees from the forest?

8. From the graph, which species of trees appeared to be relatively unaffected by the climate change of the Little Ice Age?

9. Which other species appears to have been adversely affected by the Little Ice Age?

10. The graph shows that one other species nearly disappeared, but well after the end of the Little Ice Age. What tree was this? What was the possible cause of this reduction in numbers?

Check your answers by turning to the Appendix, Section 3: Activity 1.

Activity 2: The Development of the Theory of Evolution

When you look at the fossil record, you can see the progression from single-celled fossils in the Pre-Cambrian strata to ever-increasingly complex life-forms as you move through to younger and younger rocks. The piecing together of the fossil record is one of the later groups of evidence to support the theories of evolution that were formulated in the 1800s. What were the observations of natural phenomena that led people like Jean Lamarck and Charles Darwin to develop their ideas about evolution?

Jean Lamarck (1744-1829) was one of the first scientists to attempt to explain the mechanisms of evolution. He viewed evolution as a "ladder of life," with humans on the top rung. His ideas were based on two assumptions. The first was the **law of use and disuse** in which an organism could change a body feature during its lifetime through use or disuse. A simple example would be the person who works with weights and builds up muscle mass well beyond the norm. This person has changed body features through use. Lamarck suggested that an animal like the giraffe, continually stretching its neck to reach tree leaves, would gradually lengthen its neck during its lifetime. This slightly longer neck would be an acquired characteristic. His second assumption was the **inheritance of acquired characteristics**. He believed that acquired characteristics of the parent could be passed on to the next generation. The bodybuilder's large biceps would be a trait that he believed would be passed on to his or her offspring. Similarly, the slightly longer neck gained by the parent giraffe would be passed on to the offspring. The young generation would then add length to its neck by reaching up for leaves itself. This added length would then be passed on to the next generation. After many, many generations, the giraffe's neck would have reached its present length, a length that is satisfactory to reach leaves without having to grow any longer.

1. The inheritance of acquired characteristics implies that genetic change can occur in body cells and then be transmitted to the sex cells in order to be passed on to the next generation. How does your knowledge of modern genetics show this to be false?

2. A number of experiments have been carried out to test Lamarck's ideas. One experiment was carried out on mice to see if tail length could be affected by cutting off their tails. Tails were cut off families of mice for twenty generations. Each new generation of mice had tails just as long as the tails of the original ancestors. Develop another experiment to test Lamarck's idea of inheritance of acquired characteristics. Predict the outcome of your experiment.

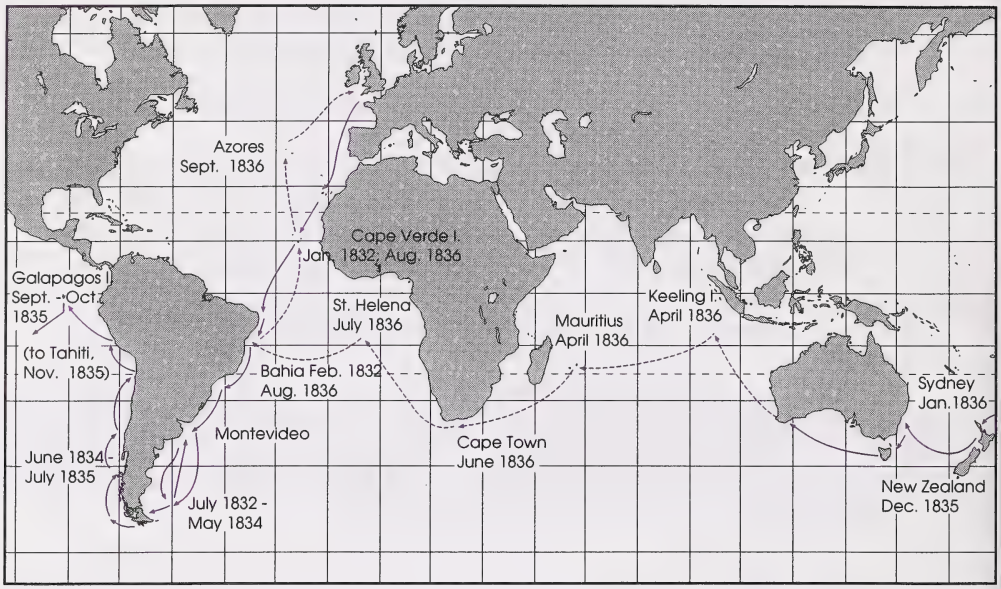
Check your answers by turning to the Appendix, Section 3: Activity 2.

It would be easy today to discredit Lamarck's ideas about evolution, but he was important in the "evolution" of ideas about evolution. You must remember that in Lamarck's time there was no knowledge about genetics and how traits were passed from generation to generation. Lamarck's ideas were based on observation of his world. He did give voice to the idea that species changed over time and that the changes were a result of the species changing to meet an environmental challenge. These were revolutionary ideas in the age of belief in the **immutability** of the species.

mmutability – ot susceptible o change

What is the name you usually hear associated with the theory of evolution? You probably thought of Charles Darwin. Charles R. Darwin (1809–1882) developed a comprehensive explanation of evolution with detailed evidence to support it. How did a wealthy surgeon's son develop a theory that is still accepted today in almost its entirety?

Darwin was following in his father's footsteps as a surgeon when, at seventeen, he decided he could not stand participating in the operations completed without any anesthetic. He then went to Cambridge University with plans to join the Church of England as a clergy. Upon graduation he decided to join *H.M.S. Beagle* on its circumnavigation as an unpaid naturalist, a decision that has had a profound effect on the way modern humans view the world. *H.M.S. Beagle* set sail in 1831 for a five-year tour as shown on the following map. The solid line represents the first half of the voyage and the dotted line represents the second half.



Darwin had little interest in evolution at the beginning of the voyage, but a book he read by Charles Lyell, *The Principles of Geology*, raised his interest. In this book, Lyell put forth evidence for the idea that the Earth had existed for a long, long time – much longer than theologians believed. This idea of geological time coupled with Darwin's observations of the plants and animals he encountered on the voyage led him to begin questioning how certain animals had developed as they did. On September 15, 1835, *H.M.S. Beagle* arrived at the Galapagos Islands, located in the South Pacific about 950 km off the coast of Ecuador in South America. Here he observed many animal species that occurred nowhere else on Earth. The Galapagos were named for the giant tortoises that lived there. He also observed the scarlet crab, the red-footed booby, and the marine iguana. He was amazed at the finches he found on the islands. Although they were clearly finches of roughly the same length and colour, Darwin observed that there were thirteen separate species occupying separate niches in the ecological community. For some reason the finches had **differentiated** into large, medium, and small sizes and diversified into seed eaters, insect eaters, tree feeders, ground feeders, cactus feeders, and so on, in various combinations. Darwin also observed that separate islands of the Galapagos group were home to separate species. He questioned first of all how the finches had arrived at the remote islands, and then how the ancestral finch that had arrived produced offspring that developed into so many separate species. What processes would you suggest to explain how that occurred? (Those processes will be discussed later.)

differentiated – developed distinguishing characteristics

Darwin left the Galapagos on October 20, 1835. In those five weeks he had collected enough data through observation to lead to the formulations of his theories. He continued on the voyage, arriving back in England in 1836. Here he began living the life of a recluse, publishing factual books simply detailing life-forms he observed on the voyage. But he was putting together many separate ideas and observations:

- Geological time is long, allowing for many changes to occur slowly over the long time frame.
- Isolated areas seem to have species much different than areas of close proximity.
- Plants and animals have different characteristics that seem to match the ecological niches in which they live.
- Through his hobby of breeding fancy pigeons, he saw how specific traits can be developed through **artificial selection**.

artificial selection – selective breeding designed to produce desired traits

- He read Thomas Malthus' *Essay on the Principles of Population* which stated that human population was in balance, and that overpopulation would strain the food supply, and that in turn would lead to the reduction of the population through starvation. Darwin applied these ideas to all life-forms. He knew that young were produced in large numbers and that not all would survive to adulthood to reproduce.

So how, by 1838, did Charles Darwin put all this together to explain evolution through the concepts of natural selection, adaptation, and speciation?

Natural Selection

Darwin saw through selective breeding (artificial selection) that certain traits present in a breeding population could be chosen by the breeder and developed into more predominant characteristics in the next generations. He took this idea and moved it into the natural world. His idea of natural selection was based on the following assumptions.

- All species display variations in characteristics; thus, each member of a species is slightly different from another.
- The number of offspring produced far exceeds the numbers that will survive into adulthood.
- Some offspring have traits that make them better able to survive successfully in their environment.
- The better adapted organisms survive to reproduce and pass their successful adaptive characteristics to their offspring.

survival of the fittest – the process of natural selection whereby the organisms with traits that make them most successful in their environment survive to become the breeding population

As a result, the population changes to better suit the environment – it evolves. This was called the **survival of the fittest** by Darwin, and is the basic explanation of evolution by natural selection.

Here is a summary of how Lamarck and Darwin differed in their ideas of the mechanics of evolution.

Lamarck's Ideas

organisms present
↓
changes in environment
↓
organisms change in response to environment
↓
organisms survive
↓
organisms pass trait to offspring

Darwin's Ideas

population or organisms with variations present
↓
changes in environment
↓
organisms with certain features are naturally selected
↓
certain organisms survive
↓
traits of selected organisms are passed to offspring

3. A number of traits are given which have proven to be successful adaptations for the species mentioned. Explain how each trait has contributed to the species to make it a winner in the "survival of the fittest."

   a. needles on a cactus

   b. the barrel shape of a cactus with photosynthesizing cells not on leaves, but on the outside skin of the barrel

   c. a jackrabbit's ability to change colour with the seasons

   d. infrared heat sensors in the facial pits of the rattlesnake

   e. a tiger's stripes

   f. a wolf living in an organized pack

4. Explain another example of natural selection that you know of that has given some organism a better chance of survival.

5. Tell the story *How the Giraffe Got Its Long Neck* according to Lamarck, and then according to Darwin, pointing out the key differences in their explanations.

Check your answers by turning to the Appendix, Section 3: Activity 2.

Darwin, as was mentioned earlier, had these ideas worked out by 1838, but hesitated to publish them until he could amass what he felt would be enough data to support his ideas against the onslaught he knew he would face from the traditional believers. Then, in 1858, he received a paper from Alfred Russel Wallace. Wallace had independently developed a theory of evolution based upon natural selection, and was asking for Darwin's input. Darwin was shocked, but pleased, as it gave him confirmation that his ideas were on the right track. In July 1858, he presented both his and Wallace's papers to the Linnean Society in London. Then in November of 1859, Darwin published his major book, *The Origin of Species*, one of the world's most influential books affecting human ideas and philosophies. It formalized the role of the scientific process in examining areas which previously were the domain of religion. The book was enormously popular, and fuelled ongoing debates between scientists and theologians that continue even today.

Modern Evolutionary Theory

Modern thought on evolution is still based on Darwin's ideas. His basic ideas have never been proven false, and scientific evidence continues to support them. This is amazing considering Darwin and his colleagues had no information about genetics, yet explained many processes like selection and adaptation. Modern theories add genetic research and detail to Darwin's basic ideas. Darwin also had only minimal information from the fossil record, yet the continual unearthing of new evidence fills in pieces of the puzzle of life's evolution and supports most of Darwin's ideas.

Darwin's keen observation of animals and their physiological relationships is an area that provides much evidence in support of evolution. This observation continues today in key areas such as natural selection, comparative anatomy, comparative embryology, comparative biochemistry, vestigial structures, and genetics. These areas are discussed briefly over the next several pages.

Observed Cases of Natural Selection

Many cases of natural selection in action have been observed. One example is the development of bacteria that are resistant to a particular antibiotic. What is the process of natural selection that leads to the resistant bacteria? Experiments carried out in the laboratory with bacteria and a previously successful antibiotic have shown that if a weak solution of the antibiotic is added to a petri dish of the bacteria, some bacteria around the edge of the antibiotic will survive. These bacteria must have possessed some trait that made them slightly resistant to the antibiotic. They illustrate the "survival of the fittest," and reproduce to produce offspring that inherit the resistant traits. Gradually the population of bacteria becomes very resistant to the antibiotic as the population is naturally selected to survive the effects of the antibiotic.

Another famous example of natural selection is that of the peppered moth in Great Britain. You will examine this case of natural selection in the form of an investigation.

Science Skills

- ☐ A. Initiating
- ☐ B. Collecting
- ☐ C. Organizing
- ☑ D. Analysing
- ☑ E. Synthesizing
- ☐ F. Evaluating

Investigation: Changes in the Peppered Moth

Purpose

Explain the changes that occurred in the peppered moth population in areas of Great Britain.

Materials

- data collected in the field about the peppered and dark form moths as shown in the Observation section

Procedure

Use the data provided in the Observations section to answer the questions in the Interpretation and Analysis.

Observations

The peppered moth in Great Britain in the early 1800s was a light-coloured moth with a dusting of dark pepper-coloured spots on its wings and body, although there was some variation in the population. The moth rested on light-coloured tree bark. In 1848, 1% of the moth population had dark wings and body. By 1898 the dark-coloured peppered moths made up 99% of the population. In the same period, rapid industrialization occurred, producing soot that darkened the bark of trees.

A related experiment was carried out in the 1950s in which dark and light peppered moths were released in areas of dark and light tree bark. The following is representative data of numbers of moths released and recaptured.

Experiment 1: In Forest with Light-Coloured Bark

Moth Type	Moths Released	Moths Recaptured	Percent Recaptured
Peppered Form	500	70	14
Dark Form	500	25	5

Experiment 2: In Forest with Dark Soot-Covered Bark

Moth Type	Moths Released	Moths Recaptured	Percent Recaptured
Peppered Form	400	56	14
Dark Form	400	116	29

Interpretation and Analysis

6. What change occurred in the environment of the peppered moth between 1848 and 1898?

7. In the 1950s experiment, what most likely happened to the moths not recaptured?

8. What would have been the reason for the differences in the numbers of moths of each colour recaptured in Experiment 1? in Experiment 2?

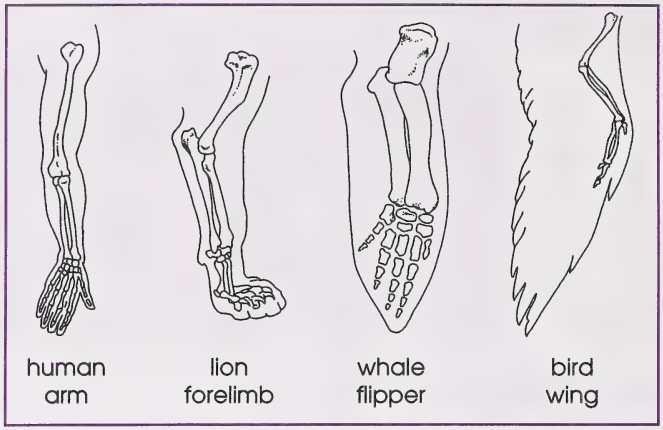
9. Putting all these details together, what caused the dramatic changes in the colour of the peppered moth between 1848 and 1898? Explain the role of natural selection in this particular case.

Check your answers by turning to the Appendix, Section 3: Activity 2.

This change in the peppered moth was the only observed change, a fairly small change in the overall organism. Other features remained the same. This illustrates the way evolution usually proceeds, by means of very small changes, most often over long periods of time.

Comparative Anatomy

Many anatomical features are similar across related species, and the more similar the structures, the more closely related the separate species are considered to be. Anatomical features that are similar in structure, development, and form are called homologous. Their presence is often considered evidence of a common ancestor. Note the similarities among these homologous limb structures.



Insects and birds both have wings that serve similar functions, but their development and structures are entirely different. The nonhomologous structures suggest they are not closely related.

Lineage through the fossil record is traced through the similarities of anatomical structures. When a new fossil is unearthed, it is examined closely to analyse its structures and categorize it with known fossils and life-forms that have the most similarities. Sometimes it will clearly fit most traits of an existing species and have only slight variations. Other times the new fossil might have so many traits at variance that it will need to be placed in an entirely new species category.

Comparative Embryology

The study of the embryos of different organisms can also show relationships among the organisms. At the early stages of development, the embryos of the human and the pig are difficult to tell apart. The more alike the development of the embryos, the closer the species are related. It is also interesting to view the evolution of the embryo in terms of the development of the individual from the fertilized egg cell to full-sized young.

Comparative Biochemistry

Biochemical similarities across species also support ideas of evolution. The hemoglobins of humans and chimpanzees, for example, are more similar than the hemoglobin of a human and a dog. This echoes the anatomical similarities which shows that the chimp is closely related to the human. Other hormones, enzymes, and so on in organisms can also be analysed to map similarities and define relationships into family trees. Of course, this is nearly impossible to do in fossil remains unless some organic materials have survived.

Vestigial Structures

Vestigial organs are structures that have no known functions in the present organism. The human appendix is one such vestigial organ. Its reason for existing is unknown. Perhaps some time in the past it did have a function, or it had some function in an early ancestor from which we evolved. We have tonsils and tailbones which have no known functions. Vestigial organs also exist in many other species. The python, for instance, along with many other snakes, has vestigial skeletal hind limbs. From the fossil record, scientists believe the snakes evolved from legged reptiles, branching off from the same common ancestor as mesosaurs and lizards.

Figure 2.10 shows that snakes are believed to have branched off from the same group of stem reptiles as the later ruling reptiles. The coloured rectangles show the period through which the reptiles lived.

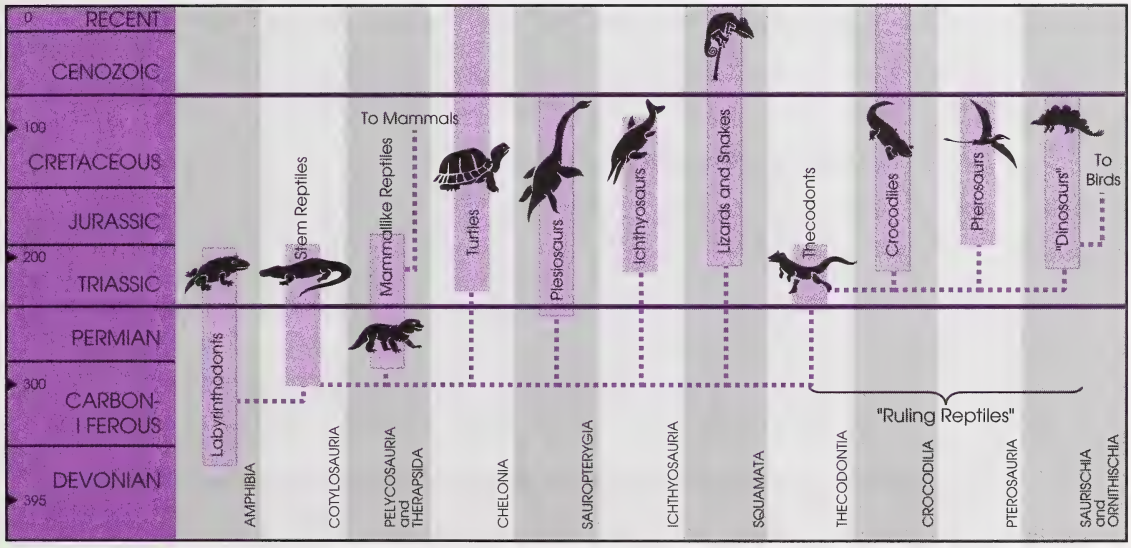


FIGURE 2.10 Evolutionary History of Reptiles

Genetics

Our understanding of genetics also adds credence to the process of evolution. For thousands of years humans have selectively bred animals and plants to improve domestic species. Beef cattle have been bred to increase growth rates and body mass. Dairy cattle have been selectively bred to increase milk production. Wheat and other grains have been bred to reach maturity in short northern growing seasons. Tomatoes have been bred to withstand the trauma of shipping. These all give support to the idea that natural selection occurs in nature, in which the fittest survive to be the breeding stock for the new generation, passing on their stronger traits to allow the offspring to successfully live in their environment.

Newer developments in genetics also have a role to play in verifying the evolution of particular species. DNA analysis is used today to trace parent-child relationships. Tests can show whether a particular organism is the parent or closely related. DNA evidence is used to place suspects at the scenes of crimes, if they have left any body materials (blood, semen, hair) at the scene. Suggestions have already been made to use DNA tracking to analyse fossil remains for familial relationships. Again, the more similarities in DNA chains, the more closely related the organisms will be. This, too, can only be carried out if enough of the organic mass of the original organism has survived to be tested. No doubt many further developments will be made in this area, judging from the rapid explosion of knowledge about DNA, genetics, and genetic engineering that has occurred over the past decade.

Populations Versus the Individual

Evolution occurs in populations over time, while the naturally selected traits appear in the individuals. Individuals of the population show natural variations in traits from each other. Successful variations are naturally selected and gradually spread throughout the breeding population. Once the entire population exhibits the successful naturally selected trait, it becomes an adaptation. Adaptations are the positive traits that help in survival and successful reproduction of the species.

How Do New Species Develop?

A key part of evolutionary theory is that modern life-forms developed from common ancestors in the distant past. If you trace the evolutionary path back far enough, all modern plants and animals have a common single-celled ancestor that lived in ancient seas. How did this ancestor develop into all the separate species you find in the fossil record and on the Earth today?

10. Based on what you have studied to this point, what processes do you think led to the differentiation of organisms into separate species? Develop an explanation.

Check your answers by turning to the Appendix, Section 3: Activity 2.

A species is a group of organisms that form a breeding population. They can successfully reproduce and produce offspring that in turn can sexually reproduce. For example, a variety of horse, such as an Arabian, can breed successfully with another variety of horse, like the quarterhorse. Their offspring will inherit qualities from each parent and be able to reproduce. A horse can breed with a donkey to produce an organism that shows traits of both, a mule; but the mule cannot reproduce. Thus, the horse and donkey are separate species, eventhough genetically close enough to allow the successful first generation reproduction. Of course, the horse and the cow are too removed genetically to be able to reproduce – definitely separate species. The horse and the cow, though, come from a common mammalian ancestor (and, since humans are also mammals, they, too, have as an ancestor that first species which exhibited more mammalian than reptilian traits).

By looking at the processes used in selective breeding you can deduce how this one ancestor developed into the number of mammal species today. Suppose horticulturalists want to develop a pure blue rose. They will first search for any existing roses that have the slightest amounts of blue pigment in their petals. They will take these plants with hints of blue and isolate them, allowing fertilization to occur only between the selected individuals. You may have seen pictures of experimental farms with bags placed over the plants' blossoms so that no stray pollen is able to fertilize the ova. The next generation is then carefully examined to find the offspring that exhibit the most blue pigment in their blossoms. Those chosen individuals are then bred. The next generation will then hopefully exhibit some individuals with even more blue petals to be used for further breeding, while many other individuals that do not exhibit the desired traits will be discarded. Over many generations a more genuinely blue rose may be developed. This blue rose will be a variety of rose, not a new species.

The new variety of rose takes a short time to develop compared to the millions and millions of years of geologic time that evolution has had to work with. The development of a new species begins when a part of a species population is isolated from the rest and therefore becomes a separate breeding population. Isolation can occur in situations like Darwin's finches, where it is believed a pair of ancestral finches were swept by storm to the Galapagos Islands, or like the separating of continents due to continental drift where many species end up having their members split on separate continents. The individuals in the separated population bring with them their specific variations that the original population may not possess. They thus begin their separate genetic route from the original population. Their particular naturally selected traits become adaptations among the entire separated population. Most changes are not that dramatic, coming from the existing genetic makeups within the breeding population that are naturally selected to suit the new environment. Sometimes dramatic traits will appear through genetic mutation, introducing completely new traits into the population. Sometimes the change in the organism is deadly and natural selection weeds out the trait. If it is a positive change that allows the individual to better survive in the environment, it becomes established in the population, becoming an adaptation.

Over many, many generations the isolated population may have become so genetically different from the ancestral population (which has also continued on its separate genetic path), that they can no longer breed and produce offspring. At this point they have become separate species.

11. Explain how the pair of finches that first appeared on the Gallapagos Island evolved into separate species.

Check your answers by turning to the Appendix, Section 3: Activity 2.

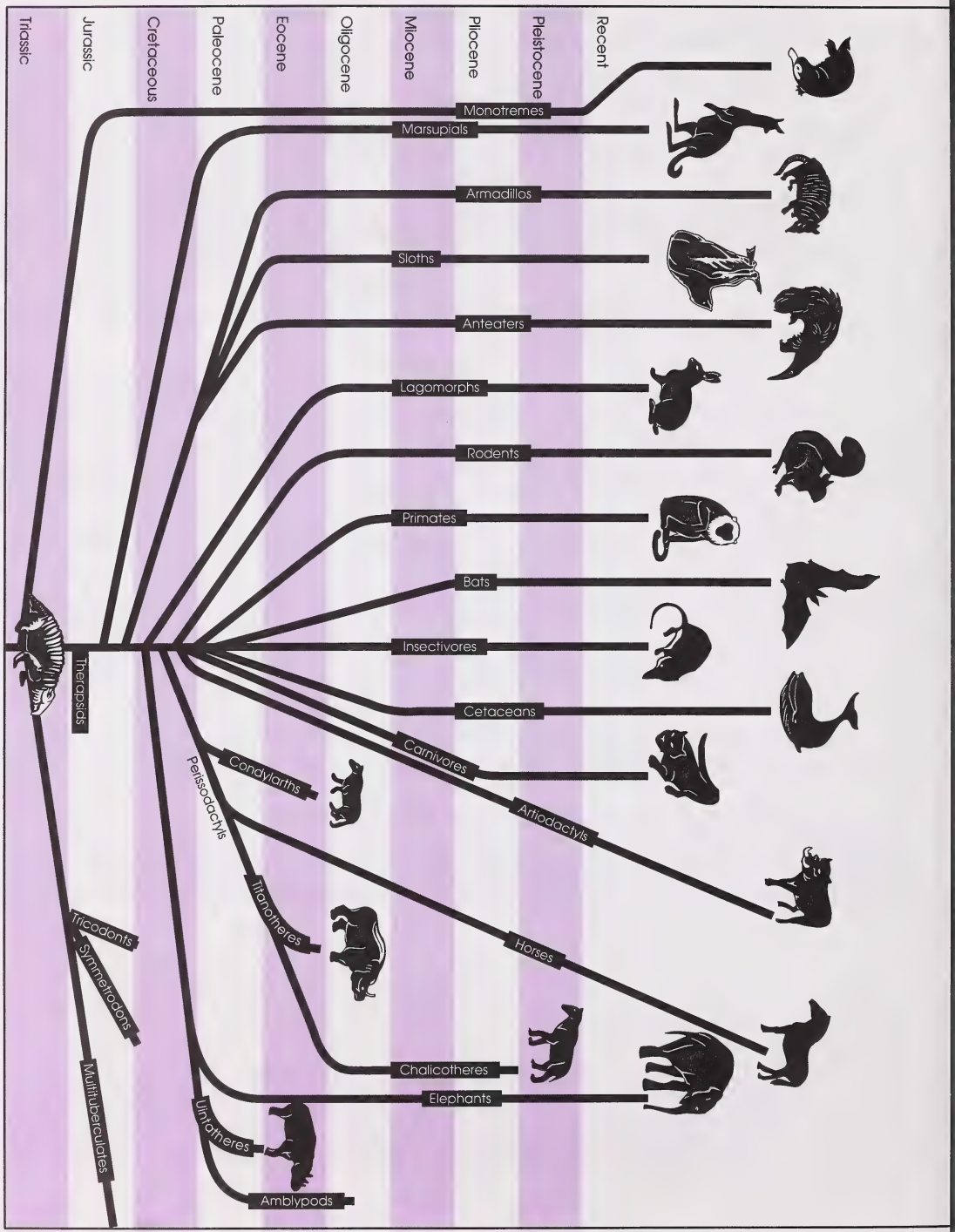


FIGURE 2.11 Simplified Representation of the Evolution of Mammals

Use Figure 2.11 to answer questions 12 to 18.

12. Humans are part of the group of mammals known as primates. When did the primate branch of mammals begin to distinguish itself in the fossil record?

13. What is shown as the common ancestor of all mammals?

14. Monotremes (like the platypus) branched away from the rest of the mammals very early in the evolution of the mammals. What are some of their characteristics that are different from all other mammals – more like reptile or bird traits? You may have to research the answer to this question in a library.

15. What are relatives of the elephant that became extinct before modern day?

16. Is a monkey more closely related to a tiger or to a sloth? Justify your answer based on the relationships shown on the diagram.

17. What is the duration of time it took for isolation, natural selection, and other genetic processes to allow the one species of ancestral mammal to develop into today's many species of mammals?

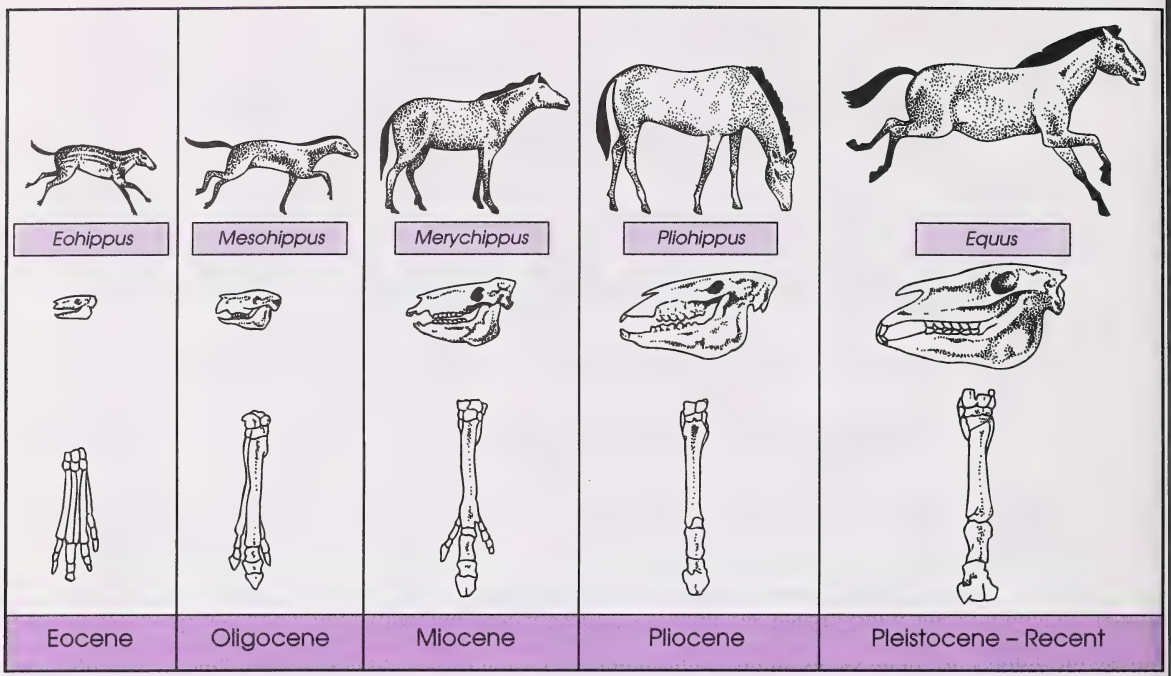
18. What is suggested by the Insectivore "straight" line?

Check your answers by turning to the Appendix, Section 3: Activity 2.

Evolution of the Horse

One of the best understood evolutionary paths is that of the horse, for a very good fossil record is evident in the Tertiary strata of North America. The earliest "horse," Eohippus, appeared in the early Eocene. Eohippus averaged 30 cm at the shoulder, had a four-toed, padded foot, and had long teeth suited for grazing for leaves in its forest habitat. The modern horse is not just a larger version of Eohippus. As the organism increased in size, its bone structure developed to support the larger mass.

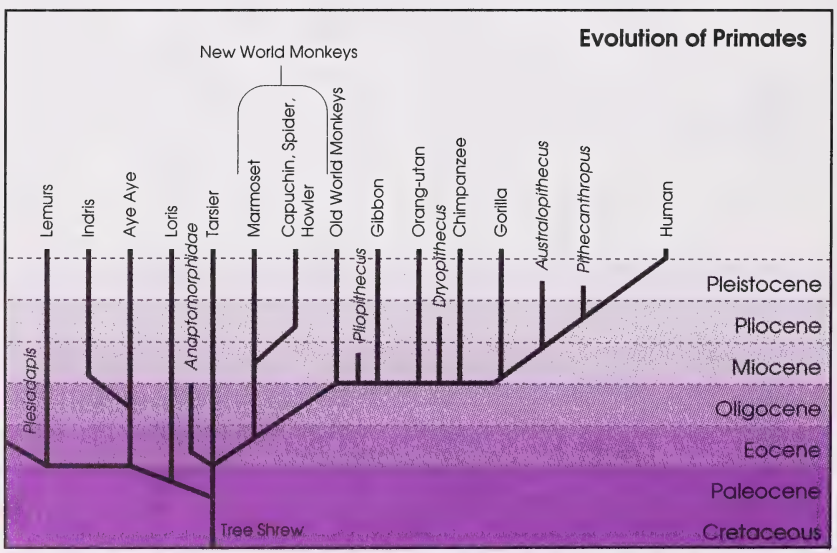
Traits in tooth structure that aided in feeding the larger animal were also selected. Fossils of the Miocene show the climate changed to support larger and larger plains full of grasses rather than forests. The "horse" evolved to better suit its new habitat. Its teeth became flatter, with increased surface area, marking the change in the organism from being a browser to a grazer. The change to one hoof and a lengthening of the legs were new adaptations to the demands of the prairie where they were very well-suited to running on the open flat ground. The relative size and complexity of the brain also increased dramatically, adding to the modern horse's ability to successfully survive. Of course, humans have used this intelligence to train the horse and make it a valued domestic animal. Selective breeding by humans continues to modify the horse, so it exhibits traits from the massive Belgian work horse to the sleek, fleet-footed thoroughbreds that need close care from humans to survive. The diagram that follows shows the evolution of the horse from early times to the present.



19. What was one of the key factors causing the traits of flat teeth and single hoof to develop in the horse?

20. Explain how the development of the horse illustrates evolution through natural selection

Use the diagram representing the evolution of primates to answer questions 21 to 25.



21. What is considered to be the common ancestor of the primates?

22. Life in the trees demanded good vision and muscular and nerve coordination. Suggest how those needs caused the development of very important traits in the primates.

23. a. Which existing species appears to be the most closely related to humans?

    b. When did the separation between that species and the human path begin to occur?

24. Explain why it is incorrect to say that humans evolved from apes.

Check your answers by turning to the Appendix, Section 3: Activity 2.

If you would like more information on Charles Darwin, view the video entitled *Organic Evolution: Darwin, Naturally.* This video is available through ACCESS Network (VC 289502).

Activity 3: Evolution and the Scientific Method

How does the development of the theory of evolution show the scientific method at work? You may wish to review the introductory material to this course that discusses the scientific process.

Most scientific investigations are triggered by observation of natural phenomena that cause some question to be raised, and then data and facts are collected through **observation** to try to make sense of the problem. Experiments are often conducted and the results observed and recorded. In other cases the natural world is the focus, and observable behaviours, events, and so on are collected. Both Lamarck and Darwin began by observing things like plant and animal traits, behaviours, habitats, and relationships.

1. a. What were some of the observations made by Charles Darwin during his voyage on *H.M.S. Beagle*.

   b. What do you think were some of the questions those observations raised for him?

Check your answers by turning to the Appendix, Section 3: Activity 3.

Darwin recorded extremely detailed data about the plants and animals he encountered during the voyage. Because he had such an acute sense of observation, he recognized minute similarities and differences in the organisms, and began questioning how such a variety of life-forms originated. But it was the observations he made in the Galapagos that raised the most questions. Many organisms there are unlike those anywhere else on Earth, but it was the existence of thirteen separate species of finches in such a small remote habitat that really raised the question of how such variations could occur. Of course, there were other observations that raised questions. For example, the fact that populations closest to each other have the most similarities, while the greater the distance apart, the more different the organisms are.

Once the initial questions were raised, Darwin set about to interpret the observations and develop an explanation, or hypothesis, that would explain the data. In the scientific process, some data and observations are pieced together to form the kernel (central part) of an idea or explanation. But often, key pieces are hidden – not yet discovered. Because the area is new, the scientist often doesn't know the questions that need to be asked to get the missing information. Detective work and inspiration play major roles in developing the hypothesis. Often it is seemingly unrelated and inconsequential pieces of information that allow the breakthrough to occur. Darwin read Malthus' ideas about human population growth exceeding the Earth's ability to sustain it. This caused Darwin to come up with his "survival of the fittest" ideas, which, put together with his personal knowledge of breeding fancy pigeons, led to the most important idea, that of natural selection, the foundation of his theory of evolution.

2. Provide a short explanation of Darwin's ideas of survival of the fittest and natural selection and their roles in the evolution of the species.

Check your answers by turning to the Appendix, Section 3: Activity 3.

Of course, as you read earlier, Darwin did not publish his ideas for many years. A scientist must verify the hypothesis with as much fact as possible, to try to prove it to be true beyond a shadow of a doubt, so it will be able to stand up under the scrutiny of scientific peers. Remember the debate about the theory of a comet's or meteorite's collision with the Earth, leading to the extinction of the dinosaurs, as illustrated in one of the two newspaper articles earlier in this module. So Darwin continued to compile data to support his ideas, and to refine them into clearer and clearer statements. He, too, knew that he would not just have to convince his scientific peers. He would be attacked by theologians, whose view of the creation of life's many species, including humans, would be threatened by Darwin's ideas. He was wholeheartedly convinced of the truth of his ideas when he found that Alfred Russel Wallace independently came up with the same theory. This has happened often in the development of scientific knowledge, where scientists working independently develop similar ideas, or make the same discovery. A case in recent years was the independent discoveries in the US and France that the HIV virus was the likely cause of AIDS.

Once Darwin published his ideas in *The Origin of the Species*, the theory was public, and took on a life of its own. Other scientists examine newly published ideas with scepticism, studying them to see if there are any cases in existing knowledge of the natural world that do not fit the theory. And other members of the public examine the ideas as well to see how they fit with their world view. The theological debates about the truth of the theory of evolution continue today.

3. Explain how work in genetics today, with scientists moving into genetic engineering and reproductive technology, is facing opposition similar to what Darwin faced when he published *The Origin of the Species*.

Check your answers by turning to the Appendix, Section 3: Activity 3.

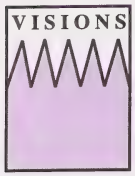
The theory of evolution and all the observations and ideas to back it up then became a part of the world's vast scientific knowledge. Additions like this trigger new ideas, new ways of looking at the world that allow scientists to piece together observations in new ways. They stimulate expanded thinking. Paleontology began basing much of its piecing together of observable fossil evidence on Darwin's ideas. When the science of genetics began to develop, its findings were compared against the ideas of natural selection. Scientific knowledge, no matter how long in existence, remains open to scrutiny. When new facts or occurrences are discovered, existing theories may be supported, they may be debunked, or they may be modified slightly to accommodate the new information. This is the case in the theory of evolution. The huge increase in knowledge about the fossil record and geologic column and the development of the field of genetics caused Darwin's theory of evolution to be modified.

4. Darwin originally suggested a timeframe of seven or eight thousand years for evolution to have allowed for the development of modern species. How did knowledge of the fossil record and genetics modify that aspect of his theory?

gradualism – Darwin's theory of evolution in which one form gradually changes into another

5. Darwin's theory of evolution is called **gradualism**. What are some occurrences in the fossil record that do not support the idea that all species gradually developed from their predecessors?

Check your answers by turning to the Appendix, Section 3: Activity 3.



New ideas about evolution have been recently introduced in an attempt to explain the mechanisms that would account for situations in the fossil record. Turn to Alternative Views Exist on the Mechanism of Evolution on pages 83 and 84 of *Visions 2*. Learn about the theory of punctuated equilibrium.

6. a. Explain the theory of punctuated equilibrium.

   b. How does it differ from Darwin's theory of gradualism?

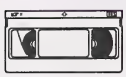
   c. What situations in the fossil record does it explain that gradualism did not?

   d. How does it still have many of Darwin's ideas as a basis?

7. a. What geologic factors does it suggest may have acted as stimulants to episodes of "punctuation" in the evolution of new species?

   b. What explanations can you give for how those geologic changes could cause such rapid evolution at those points in time?

Check your answers by turning to the Appendix, Section 3: Activity 3.



For more information on gradualism and punctuated equilibrium, you may view the video entitled *Natural Selection, Part 2 – Gradualism Versus the Punctuated Equilibrium Theory of Evolution.* This video is available through ACCESS Network (VC 359100).

The basic ideas that made up Darwin's theory still appear to be true, with major modifications represented by the proponents of punctuated equilibrium to better explain new facts unearthed through continuous scientific search. No doubt new evidence will continue to be collected which may modify the theory in the future. Maybe new techniques and technology will allow scientists to trace fossil organisms genetically to clearly establish evolutionary lineages through the fossil record. Today, debate continues over the theoretical "how" of evolution. In science these debates are healthy, keeping the vigour in the scientific process.

Follow-up Activities

If you had difficulties understanding the concepts in the activities, it is recommended that you do the Extra Help. If you have a clear understanding of the concepts, it is recommended that you do the Enrichment.

Extra Help

Development of Earth's Atmosphere

Early Earth had little or no atmosphere, but soon volcanic activity began adding gases like nitrogen, carbon dioxide, and so on to create the first atmosphere. The lack of oxygen allowed organic chemical compounds to build up in the ocean waters of the planet. These compounds gradually developed into life-forms. Once they evolved into blue-green algae that could carry out photosynthesis, oxygen started to be added to the atmosphere. Once oxygen built up, ozone began to be created. The protective ozone layer allowed more complex plants to develop, thus increasing the amount of oxygen being fed into the atmosphere. Over time our present atmosphere developed. The complex interrelationships of many processes that created our atmosphere is a mirror of the processes and cycles that play a role in most of the geological and life events on the Earth.

Evolution

Evolution in the biological sense is the process by which the genetic makeup of a population of organisms changes over time. Jean Lamarck and Charles Darwin developed theories to explain change in organisms. Lamarck suggested that change was through the individual. The individual organism changed its traits in a lifetime, such as an early horse racing across open land strengthening and lengthening its legs. This trait of longer legs would then be passed on to its offspring. These offspring in turn would lengthen and strengthen their legs more by running across open land, and these even longer legs would be passed on to the next generation. After many generations, the long legs of the horse became the common trait across the population.

Darwin's explanation is the accepted one. He said that a variety of traits are present in the population. For example, in the early horse population, some horses had longer legs than others, some had shorter legs, some had stronger legs for faster running, and so on. As the environment gradually changed to grassland, the horses that could run faster had a better chance for survival. They were winners in the "survival of the fittest." The traits of longer legs and hooved feet were "naturally selected" because these are traits that made the horses faster and able to survive predators. Generation after generation the "fittest" horses survived to add the genes for their successful traits to the population pool and these traits became the norm for horses.

1. a. Explain how Lamarck would explain the development of a carnivore's sharp teeth.

   b. How would Darwin explain the development of a carnivore's sharp teeth?

Check your answers by turning to the Appendix, Section 3: Extra Help.

Species are defined as those organisms that can breed with each other and produce offspring. In other words, different species cannot successfully breed with each other. The theory of evolution demands that one species develops from another; in fact, all living things originated from a single ancestral species. How can one species develop from another? A main requirement is isolation. Suppose the population of an organism split so one group is in one environment and the rest are in a different environment. Natural selection comes into play, as do the particular traits that the individuals of each group possessed. Over time the traits that make each group successful in its own particular environment will come to the forefront. Over time the changes in each group may become so different that the members can no longer interbreed if they were put together. Thus, they have become separate species from common ancestors.

2. Explain how the chimpanzee and the gorilla developed to be separate species coming from a common ancestor.

Check your answers by turning to the Appendix, Section 3: Extra Help.

Enrichment

1. Since Darwin published his book, *The Origin of the Species*, proponents of the theory of evolution have been embroiled in controversy with traditional theologians. Perhaps the greatest public examination of the issue was the Scopes' trial in the United States in which a biology teacher, John Scopes, was taken to trial for teaching about evolution in his classroom. You may want to research this trial to find the main arguments given on each side. The famous play *Inherit the Wind* by Jerome Lawrence and Robert E. Lee presents a dramatic version of the trial. It makes for interesting reading.

2. Some churches with traditional biblical viewpoints have presented an alternate theory to evolution called creationism. You may wish to research this alternate view.

3. A dramatic explosion of knowledge about DNA, genes, and chromosomes has occurred in the last decade. Scientists now do genetic engineering and gene splicing. New techniques have been developed in reproductive technologies. Cloning of organisms is carried out. You may wish to research these new breakthroughs and examine their impacts on science – and the impacts they will have on economics, and on human beliefs and ethics.

Check your answers by turning to the Appendix, Section 3: Enrichment.

Conclusion

You have studied in this section the process of evolution. In its broadest sense, evolution simply means a gradual change from one form to another. The early atmosphere of the Earth was very different from that of today. You studied the interrelationships of various processes, like the carbon, oxygen, water, and rock cycles, and how they all worked together to change the early inhospitable atmosphere to one that supports life. Related to this is the role of evolution in the development of the multitude of life-forms on our planet. Charles Darwin was one of the first scientists to show how natural selection and the idea of the survival of the fittest played major roles in evolving species to better fit in their environments. His theory also explained how a species could evolve into new species due to natural variations in the populations if they became isolated into separate breeding groups. Darwin's theory of evolution is called gradualism: the slow and steady evolution occurring at about the same rate throughout time. The fossil record shows, though, that there were long periods of relatively little change in the evolution of species and then sudden extinctions of many species and rapid evolution of new species to take their places. Darwin's original theory has been modified by these new ideas of punctuated equilibrium. Your studies in this section can't help but make you ponder your own place in geologic time and the evolutionary path that led to you as an individual.

ASSIGNMENT

Turn to your Assignment Booklet and do the assignment for Section 3.

MODULE SUMMARY

The material you covered in this module has given you information to analyse and describe the rocks and fossils you may find in your travels around Alberta. First you studied sedimentary, igneous, and metamorphic rocks and the rock cycle that is constantly changing the forms of the rocks on the Earth's crust. Stratigraphy gives you the tools to make sense of the rock strata you see exposed in the mountains, the badlands, and other valleys and cutaways around the province. The study of Alberta's rich fossil heritage gives you a sense of our prehistory and the diverse landforms, climates, and life-forms that existed here throughout geologic time. You have seen how this heritage has provided our province with economic riches, both in tourism dollars and the royalties and economic spin-offs from the natural resource industries. Then you learned about the development of the theories of how life today came to be – through the theories of evolution. All these ideas are tied together by similar themes: the interrelationship of processes and cycles and the role of the scientific process in developing theories and testing ideas through collection of data and logical analysis. Hopefully you have gained an appreciation of the rich history of our province. In the next module you will move on to study more about cycles and processes of matter and energy transfer in the day-to-day life processes on our planet.

Appendix

Glossary

Suggested Answers

Glossary

artificial selection: selective breeding designed to produce desired traits

carbonification: process by which original material is replaced by or surrounded by a carbon layer

chemical sedimentary: a rock type formed from the precipitate of a chemical solution

clastic sedimentary: sedimentary rocks that are formed by minerals being deposited into the spaces between the rock particles, cementing these particles together

differentiated: developed distinguishing characteristics

foliation: structure of metamorphic rocks where clear layers or bands that are easily cleaned are visible

fossil: any preserved evidence of past animal or plant life class

gradualism: Darwin's theory of evolution in which one form gradually changes into another

homologous: having the same structure, development, and form

igneous: class of rock formed from cooling magma or molten rock

immutability: not susceptible to change

impermeable: cannot be penetrated

lithification: process by which particles are cemented together

magma: molten rock beneath the Earth's crust

metamorphic: class of rock formed when other rocks have been changed by heat or pressure

observation: watching for some special purpose

organic sedimentary: a rock formed from the remains of living organisms

paleobotanists: scientists who study fossil plants

pegmatite: coarse variety of granite

periods: portions of time that are based on recognizable crustal changes that occurred in one or more areas

petrification: process by which plant or animal life is preserved through dissolved minerals replacing the original cell material

relative: in relation to one another

rock cycle: process whereby rocks change from one rock class into another

sedimentary: class of rock formed by particles of material deposited in layers

silicified: converted into or filled with silica

stratigraphic columns: complete sequences of rock layers for a particular rock outcropping

stratigraphy: the study of rock strata and their sequence or order

survival of the fittest: the process of natural selection whereby the organisms with traits that make them most successful in their environment survive to become the breeding population

symbiotic relationship: a relationship between two or more species that live in close association

unconformity: some type of change that has occurred between older rock and younger rock

Y 400 000: 400 000 yuan
The yuan is the currency used in mainland China.

zone fossils (index fossils): fossils that are well preserved and occurred in many parts of the world but for a relatively short period

Suggested Answers

Section 1: Activity 1

1. Answers will vary depending on the samples that you obtained. Answers are provided for one sample.

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
Individual Particles Seen (yes/no)	yes				
Particle Size	coarse grain (1.5 mm to 2.0 mm)				
Surface (rough or smooth)	rough where broken; smooth where worn				
How are Particles put Together?	interlocking crystals				
Reaction with Vinegar (fizz/no fizz)	no fizz				
Smells Like Mud When Wet (yes/no)	no smell				
Contains Plant or Animal Markings (yes/no)	no fossil markings				
Colour of Particles	grains are pink, white, and black				

2. Answers will vary depending on the samples you obtained. You will need to deduce from all the characteristics which types of rock your samples most closely fit. Sedimentary and igneous rocks will probably be the most recognizable and will account for most of your samples. The sample characteristics indicated in question 1 most accurately describe granite, an igneous rock.

3. Extrusive igneous rock is formed when magma moves up to the surface of the Earth through volcanoes and cracks in the crust and cools quickly.

   Intrusive igneous rock is formed by magma which only makes it part way through the Earth's crust, never reaching the surface and cooling slowly underground.

4. a. Large mineral crystals are formed in intrusive igneous rock, as the slow cooling allows the minerals to collect and grow large crystals.

   b. Small mineral crystals are formed in extrusive igneous rock, as the rapid cooling at the surface allows little or no crystal growth.

5.

Characteristic	Photo 1	Photo 2	Photo 3
General Appearance	looks like melted sugar, very dense looking	dense, fine material with pebbles distinct layer of pebbles near bottom	looks like coal cinder material, large gas bubbles
Crystal/Grain Structure	no grain visible	fine-grained with smooth-looking pebbles	fine-grained
Organic Composition	no	probably not, although some of the pebbles could be coal	no
Layering	layers appear melted together	a layer of pebbles along the bottom of the rock	no
Foliation	yes	no	no

6. In Photo 1 the grains or crystal structure appears to have melted together. In Photo 2 the grain in the upper layer is quite fine, while the grain in the bottom layer is coarse with various-sized pebbles visible throughout. In Photo 3 the grain is very fine with gas bubbles throughout.

7. In Photo 1 the rock has signs of layering that appears to have flowed. Photo 2 has a distinct layer of larger pebbles near the bottom. Photo 3 has no signs of layering.

8. Photo 1 shows a metamorphic rock (marble).
   Photo 2 shows a sedimentary rock (sandstone/conglomerate).
   Photo 3 shows an igneous rock (vesicular basalt).

9. The rock in Photo 1 looks like it was heated or forced by pressure until it started to flow. This is characteristic of metamorphic rocks. The rock in Photo 2 has fine, evenly-sized grains with a distinct layer of pebbles in it. This would suggest sedimentary rock. The rock in Photo 3 has a burnt out or volcanic rock type appearance. Gas bubbles occur only in volcanic rocks. Thus, the rock in Photo 3 is igneous.

10. Sedimentary rock is most likely to have spaces between particles because it has been formed from separate particles of other types of rock. Some igneous rock also has spaces between particles formed when lava cooled quickly enough to trap gas bubbles.

11. Answers will vary. Did any of your samples match the three samples in the photographs provided here? If you have any samples which have traits not described or which do not seem to fit any classification, you may want to ask your teacher or facilitator about them. You may also look for information about your samples in other reference books.

12. The full rock cycle produces the following materials: magma, igneous rock, sediment, sedimentary rock, and metamorphic rock. The four processes in the rock cycle are crystallization, metamorphism, weathering and deposition, and lithification.

13. One shortcut occurs when igneous rock is transformed directly to metamorphic rock by heat and pressure (metamorphism). This is a shortcut because usually igneous rock would have to go through the processes of being eroded to sediment and becoming sedimentary rock before becoming metamorphic rock.

14. The movement of the tectonic plates is one factor that drives the rock cycle. As the plates move, molten rock in the mantle and core is allowed to circulate upward toward the surface of the Earth where the plates separate . The magma will then cool and crystallize to form igneous rock. At the same time, some rock is pushed down (subducted) where plates meet and one plate is forced under the other. The igneous rock is melted to magma. This change in position of rock drives the creation of new rock states in the rock cycle. The collision of plates also causes mountain building. The strata will be metamorphosed through heat and pressure. The uplifted mountains will also be more exposed for erosion to occur.

15. The theory of isostasy says that the less dense rock found on or near the surface of the Earth floats over the denser rock in the mantle. As the rock formations on the surface of the Earth are eroded, the load of the surface rock is decreased. When the eroded sediments are deposited on the ocean bed, the load there is increased, forcing the crust to move downward. This motion increases the load on the molten rock in the mantle. The increase in the load on the molten rock in the mantle causes the crust in the eroded area to move upward. As the crust moves upward, more rock is exposed and eroded, beginning the cycle again. In this way the concept of isostasy can be used to explain the continuation of the rock cycle. The constant movement in the crust can also create cracks which allow magma to intrude upward, cool, and form igneous rock.

Section 1: Activity 2

1. a. The snail shell is a fossil. It is an actual remain of a once living organism.

   b. The tracks in sandstone are fossils because they are imprints of an animal which lived before the modern epoch.

   c. A tree stump in the forest is not a fossil in the sense that is has not been "preserved." It has not been buried and removed from oxygen, and is too recent to be classed as a fossil.

   d. The human skeleton is not yet a fossil because it is the remains of a life-form that lived in recent geologic time.

   e. The markings of a clam shell on a rock is a fossil because it has the imprints of a living creature, provided the rock was formed before the modern epoch.

   f. The Okotoks glacial erratic is not a fossil because it was never a living organism.

2. For preservation to be successful, an organism must be removed from its oxygenated environment and from scavengers and decomposers. This is necessary so that decay and deterioration do not occur. The best conditions for preservation are found under many layers of sediment, usually on the continental shelves of the oceans or freshwater swamps and lakes.

3. a. The first-layer fossils will be impressions of the original organisms. You should be able to see in reverse the distinct markings or characteristics that are present on the original organisms or objects.

   b. The second-layer fossils will have the shape and form of the original organism or object.

4. The first fossil is an imprint or mould of the original organism or object.

5. a. The second fossil is a cast of the original organism or object.

   b. The first layer has an impression where the organism or object was. The second fossil has the actual shape and form of the original organism or object.

6. This method is much faster than the natural formation of fossils. The process would naturally occur over thousands of years. The natural process of fossilization also involves a great amount of compression from many layers of sediment. The imprint or mould would be formed in the same way with a real fossil, but the process of forming a cast is somewhat different. The original shell is usually dissolved, leaving a hollow that is filled by mineral-rich solutions which leave minerals that gradually fill the hollow.

7. Most fossils are found in sedimentary rock because fossilization is much more likely to occur due to an organism being covered by layers of sediment on the ocean floor or on lake beds . Since most parts of the world have been under water at some time in history, most sedimentary strata around the globe contain some type of fossil. Igneous rocks are formed from magma, which would completely destroy any organism with which it comes in contact. Metamorphic rocks formed from sedimentary rocks may contain fossils, but they will usually be changed beyond recognition by heat and pressure.

Section 1: Activity 3

1. Mechanical weathering is due to the movement of wind, water, ice, or some other force across the surface of the Earth's crust. Chemical weathering is due to the presence of chemicals in the environment. These chemicals "eat" away and help dissolve minerals in rock.

2. a. Clastic sediment is sediment that has been formed from "pieces" of eroded materials which have been solidified into solid rock by pressure forcing out any spaces between particles or by dissolved minerals cementing the particles together.

   b. The four main types of clastic sediment are conglomerates, sandstones, limestones, and shales.

3. Sediment is moved and deposited by wind, water, and ice or by force of gravity (landslide).

4. a. pebbles, sand, clay, silt

   b. In the first diagram, the stream flow is from right to left. In the second diagram, the stream flow is from left to right. The current is greater in the second diagram. This is indicated by the position of the different types of sediment. The area covered by each type of sediment is spread out more horizontally than in the first diagram, as the current carried the sediment further . It would take a stronger current to be able to carry the particles further.

5. compaction – Pressure increases as layer upon layer of sediment is deposited, pressing particles together and even distorting them, squeezing them so there is no space remaining.

   cementation – Chemicals precipitate around particles, "gluing" them together.

6. Limestone is formed when calcium carbonate from the shells of many types of shallow-water animals which collect on the sea floor form a layer of sedimentary strata. Pressure compacts the layer into limestone. The layer sometimes also includes amounts of sand or clay.

7. Glacial valleys, lakes, beaches, river deltas, and the sea floor are all locations where deposition by water occurs.

8. That statement is based on the principle of uniformity. Processes that can be observed today are the same processes that created sedimentary strata in the geologic past. You can see how material is weathered and eroded, and deposited by rivers, streams, beaches, and so on, today, and therefore read the strata to see how they were laid down in the past.

9. a. The principle of original horizontality is that sedimentary strata are laid down in horizontal (flat) beds.

   b. Sometimes sloping deposition occurs, as when wind deposits sand in the form of dunes. Any layers added to the back side of the dune will be sloping. Similar angled layers will be deposited on sandbars and stream deltas.

10. a. Crossbedding is the deposition of angled layers of sediment, cutting across normal horizontal layers.

    b. The velocity of wind or water can change the angles of the crossbedded layers. The crossbedded layers may be eroded and then new crossbedding may resume over them. The crossbedding reveals the shifting around of streams and direction of currents.

11. a. Ripple marks can tell the location of an ancient beach and how it moved as water levels increased and decreased. These marks can reveal the direction of the waves or current, and even the strength of the current.

    b.

    Note: This is a cross-section view. Imagine you are looking into the bed from the side.

12. a. Mud cracks would form in an area where the lake floor was drying up – a lakeshore or bay with receding water. Later the water level rose again and filled the cracks with sediment. The formation became rock and so can be observed today.

    b. They can reveal the locations of ancient shores or bays, and by tracing their locations and movement, scientists can trace the increase and decrease in water levels.

13. The traits suggesting the strata formed in fresh water are as follows:

    - thick successions of fine-grained deposits
    - thin beds
    - long lateral layers
    - strata with freshwater fossils
    - preserved mudcracks
    - ripple marks

14. Rivers show many differences in bed thicknesses, coarse-grained deposits, and scour-and-fill deposits, as compared to the lake characteristics detailed in question 13.

15. a. These are some of the resources which come from sedimentary rocks and some of the uses of sedimentary rocks today: fossil fuels, building materials (cement, gravel, sand), iron ore for steel, bauxite for aluminum, brick and tile, cut stone, and asphalt.

    b. Answers will vary depending on the area in which you live. You should have found things like cement, tiles, brick, steel (for example, in vehicles and machinery), coal, oil, and so on.

16. a. The oldest rock layer is layer A.

    b. The youngest rock layer is layer F.

    c. Layer A was deposited first. Layer F was deposited last.

    d. Layers D, E, and F are younger than layer C.

17. a. The layers in Figure 2.4 from oldest to youngest are H, G, F, E, D, C, B, A.
    The layers in Figure 2.5 from oldest to youngest are H, G, F, E, C, B, A, D.

    b. The principle of original horizontality and the principle of superposition was used to order the layers in the first diagram. An unconformity (the tilted layers and their erosion) is also present but not labelled.

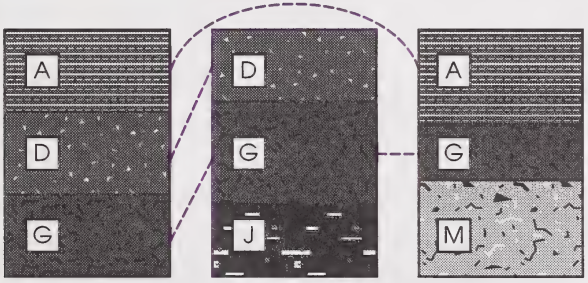
    c. The principle of original horizontality, the principle of cross-cutting relationships, and the principle of superposition was used to order the layers in the second diagram.

18. a. Zone or index fossils are fossils which have a limited range in geologic time (they appear for a relatively short time in the fossil record), and are widespread geographically.

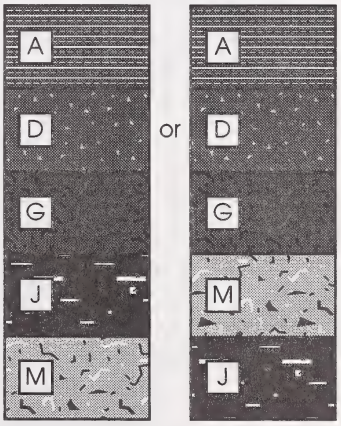
    b. Rock strata with the same zone fossils are correlated to having been laid down at similar times, no matter how far apart geographically.

19. William Smith's ideas led to the idea of faunal succession, the principle that states that the fossil record shows a definite progression from oldest to newest, from simplest life-forms to more complex. His work also led to the correlating of rock strata worldwide, often made possible by using zone fossils.

20. a.



b.



21. a. The missing layers were probably eroded away.

    b. These missing layers, being eroded away, are called unconformities.

22. a. Layer A – The most recent layer.

    Layer B – Sand indicates a possible drought. This makes sense because of the presence of charcoal and the wood remains of fire, since dry conditions would promote fire. It could also have been the edge of a lake or sea.

    Layer C – The glacial deposit indicates environmental change. Before this period in time the environment had been good for growing. The ice age may have come on quite quickly. It was most likely the glacier that caused the unconformity between C and the lower layers.

    Layer D – Leaf fossils indicate that conditions were acceptable for growth. The poplar leaf fossils suggest a temperate climate. Sandstone indicates that the ocean that was present in Layer E had become shallower, for sand, being fairly heavy, is deposited near the ocean or lake shore.

    Layer E – The shale with crack marks indicates that there definitely was a body of water which dried up, leaving the cracks. The fact that the rock is shale is evidence that the body of water was fairly deep and received significant clay and silt deposits. Shale is formed from clay and silt that, being very light particles, are deposited far from the shore in deeper water.

    Layer F – Sandstone with clam shell fossils is evidence of shallow seas.

    Layer G – The sandstone over the oil deposit is evidence that there had been aquatic plants and animals which accumulated on the ocean floor when they died. They then were covered by the layer of sediment which formed the sandstone. The lack of oxygen once they were buried, the pressure from the sandstone layer and the layers which were to eventually form above it, and other factors caused the plant and animal remains to be turned into oil.

    Layer H – Coarse sandstone indicates that the area was near the shoreline of an ocean. There doesn't seem to be any aquatic organism fossils present, so possibly there wasn't any aquatic life at that time.

    Layer I – The volcanic ash indicates that there was volcanic activity occurring at this time. This was probably the reason why there wasn't any aquatic life indicated in Layer H.

    Layer J – The black, carbon-rich material may be uncompacted coal. This seems likely because of the presence of many fern leaf fossils in the material. During this time period the climate must have been tropical, allowing for the growth of ferns.

    Layer K – The red shale indicates that the ocean had dried up and allowed the shale to oxidize before it was covered by another layer.

    Layer L – The shale indicates that an ocean once again covered this area. There is little oxidation, so the ocean must have been deep.

    Layer M – The presence of this kind of fossil indicates that there were more sophisticated organisms on land. The environmental conditions must have been right for supporting more sophisticated types of organisms. This means that the ocean that had been present had dried up completely.

Layer N – The hard sandstone was formed by the process of lithification (being cemented together by dissolved minerals). Since sandstone is formed from coarser materials than clay, the ocean that was in Layer O must have started to dry up and become shallower.

Layer O – The presence of clay indicates that this area was under a deep sea at this period of time. This sea must have been formed after the volcanic activity that took place in Layer P.

Layer P – The volcanic ash indicates volcanic activity and the creation of new rock formations.

Layer Q – This the oldest exposed layer because it is positioned at the bottom of the column. There is no indication of what this layer is composed of.

b. **Textbook question 1:** Answers will vary, but you should have answered that this layer is older than 225 000 000 years because the volcanic ash layer above is dated at 225 000 000 years.

Textbook question 3: The information from the column can only tell you that *Albertosaurus* lived more than 60 000 000 years ago and less than 225 000 000 years ago, the only dated evidence given.

Textbook question 4: The differences between the layers may be due to the depth of the ocean they were under and how quickly other layers were formed above them and cut off the supply of oxygen which caused the oxidation. There may also have been slight differences in the composition of each layer. The environmental conditions at the time would affect the chemical composition. Layer K may have had significantly more iron in it.

Textbook question 5: The climate suggested by Layer J is a tropical one. This is shown by the high content of fern leaf fossils. Ferns are tropical plants. It suggests this may have been a coal-forming swamp.

Textbook question 6: This layer is just older than 60 000 000 years. It is probably from the Cretaceous Period.

Textbook question 7:

Layer D – Leaf fossils indicate that conditions were acceptable for growth. The poplar fossils suggest a temperate climate. Sandstone indicates that the ocean that was present in Layer E had become shallower.

Layer E – The shale with crack marks indicates that there definitely was a body of water which dried up, leaving the cracks. The fact that the rock is shale supports the evidence that the body of water was fairly deep and received significant clay and silt deposits.

Layer F – Sandstone with clam shell fossils is evidence of shallow seas.

Layer G – The sandstone over the oil deposit is evidence that there had been aquatic plants and animals which accumulated on the ocean floor when they died. They then were covered by the layer of sediment which formed the sandstone. The lack of oxygen once they were buried, the pressure from the sandstone layer and the layer which were to eventually form above it, and other factors caused the plant and animal remains to be turned into oil.

Layer G is probably impermeable, preventing the oil from moving through it. All the layers were exposed to forces which folded them. Then layers D, E, and F were most likely eroded by glaciation.

Textbook question 8: Layers D through G were folded, possibly in an episode of mountain building. Then they were severely eroded for a long period of time – either by weathering, but most likely by the glaciation that left the glacial deposits in Layer C. It is difficult to know if there were other layers between D and C that were also eroded away, making a complete geological record difficult.

Textbook question 9: Layer D is sandstone formed from lake or ocean deposits in temperate climate, based on the presence of poplar leaves. Layer C is a glacial deposit. This means that the climate changed significantly to one that would allow glaciers to develop.

Section 1: Activity 4

1. You could measure an earthquake, a volcano, or a landslide using small time scales. Sometimes erosion can occur quite quickly. Other geologic events occur over much greater periods of time.

2. The estimated age of the Earth is about 4.5 billion years.

3. Answers will vary. Your calendar should have had the dinosaurs appearing on about December 15, humans at about 11:20 pm on December 31, and the Industrial Revolution occurring at about one or two seconds before midnight.

4. Answers will vary. Your story should reflect the suggestions given in the Analysis and Interpretation section of Activity 2.1 in *Visions 2*. You should have discussed how early times had few events occurring over large time spans while the end of the time scale shows a large number of events.

5. James Hutton recorded that streams carrying sediments, basins where rivers emptied into the sea, and layers that uplifted and tilted were evidence of land buildup.

6. James Hutton was the first to state that the Earth must be very old, at least millions of years. He also began systematic recording of geological processes like erosion, deposition, land uplift, rock layering, and so on.

7. principle of uniformity – The geological processes at work now are the same ones that were at work throughout history.

   principle of original horizontality – Sediments are originally laid down in horizontal layers.

   principle of cross-cutting relationships – Features that cut across or affect strata are younger than the layers they affect.

8. Eras are the largest units of time on the Earth's time scale. There are four eras in geological time: Precambrian, Paleozoic, Mesozoic, and Cenozoic.

9. The divisions between the different eras were determined by major environmental or geological changes as shown by evidence in the fossil record or geologic column.

10. Periods are based on changes in the Earth's crust that occurred in one or more areas. Epochs are determined by the rise and fall of sea levels or the rise and fall of land masses.

11. The recent parts of the time scale are smaller because many changes have occurred in recent geological history. Because it is relatively recent, fossils have not been destroyed, and strata is nearer the surface so it is easily studied. Therefore, it is easier to recognize major events that are used to decide geological time divisions.

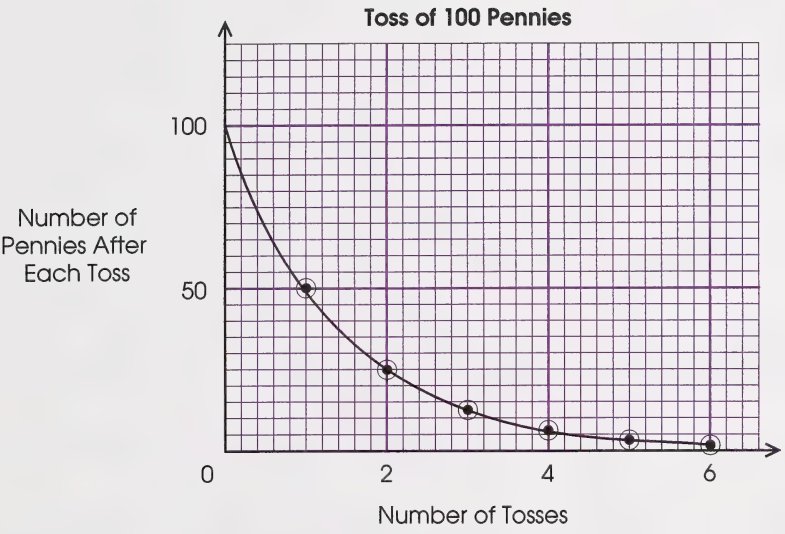
Section 1: Activity 5

1. Some variables that would make this way of estimating inexact are as follows:

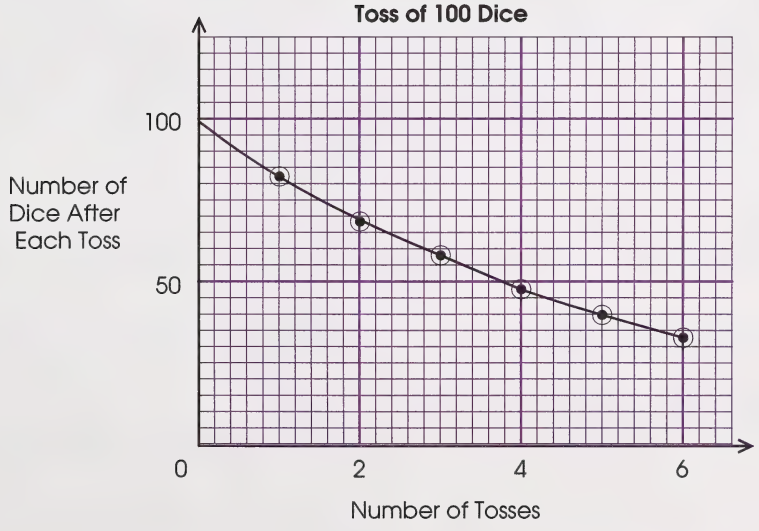
   - Amounts of sediments being deposited vary greatly.
   - Types of sediment vary.
   - Amounts of salt deposited in the oceans and seas vary.

2. Your graphs for Parts A, B, and C should be similar to the following. Part C is done for two tosses. It will take more than two tosses to eliminate the nickels.

Part A



Part B

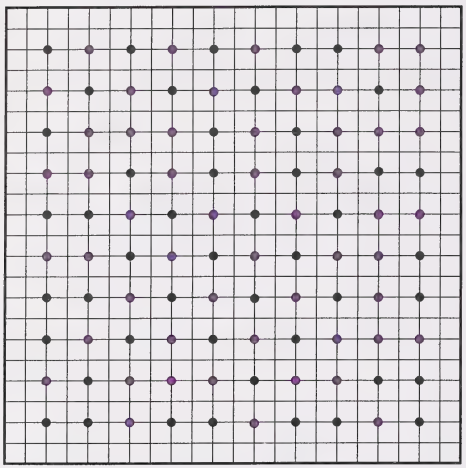


Part C

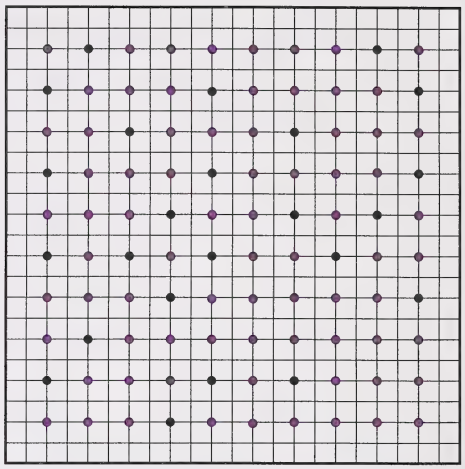
Toss of 100 Nickels and Replacement with Pennies

• nickel
• penny

Toss 1



Toss 2



3. **Textbook question 1:** The fixed fraction in Part A should be one-half. The proportion left after each toss is approximately one-half of the number of the previous toss.

   In Part B the fixed fraction is one-sixth. The proportion left after each toss is approximately five-sixths of the number in the previous toss.

   Textbook question 2: The half-life for the pennies in Part A is one toss, since it took only one toss to reduce the number of pennies to approximately one-half of the original number. The half-life for the dice in Part B is about 4 tosses, since it took four tosses to reduce the number of dice to approximately one-half of the original number. The dice have a longer half-life.

   Textbook question 3: The parent material in Part C was the original 100 nickels. The daughter material was the pennies that replaced the nickels. The total quantity of material (number of coins) remained the same throughout. The quantity of the parent material decreased over time. The quantity of the daughter material increased over time.

   Textbook question 4: Your graph should look like the one in Figure 2.2 on page 48 of your textbook.

   - The area above the curve represents daughter material. The area below the curve represents parent material.
   - Half has decayed. Half is left.
   - Seven-eighths has decayed. One-eighth is left.
   - As the mass of parent material decreases, the amount of daughter material increases proportionally.

Number of Half-lives	Amount of Parent Material (g)	Amount of Daughter Material (g)	Number of Half-lives	Amount of Parent Material (g)	Amount of Daughter Material (g)
5	3.125	96.875	8	0.3906	99.61
6	1.563	98.44	9	0.1953	99.80
7	0.7813	99.23	10	0.09766	99.90

Note that the calculated amounts have been rounded to four significant digits. As you can see, the amount of parent material gets less and less. After about fifteen half-lives the amount left will be very small, but there will always be some left.

- After three half-lives the ratio of daughter material to parent material is 87.5 : 12.5. From Figure 2.2 in *Visions 2*, approximately three-eighths of a half-life has elapsed when 75% of the parent material remains.
- Since two half-lives have passed, the age of the sample is 9.02×10^9 a.

Textbook question 5: Answers will vary.

The six-sided die has a longer half-life because more outcomes are possible. It takes longer to remove them all.

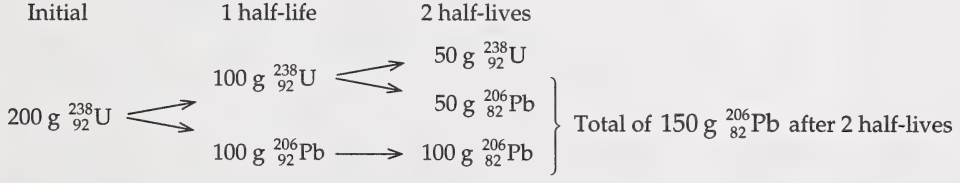
See the answer for question 2 in Section 1, Activity 5. Compare the parts you completed.

See the answers for questions 3 and 4 in Section 1, Activity 5.

Textbook question 1: The radioisotope column represents the parent material. The decay product column represents the daughter material.

Textbook question 3: Approximately $\frac{1}{16}$ of the original material will be present after four half-lives.

Textbook question 5: Approximately 150 g of the daughter material $\left({}^{206}_{82}\text{Pb}\right)$ will be present after two half-lives. Note that for simplicity in this calculation the loss of the ten protons per atom (92 to 82) has not been considered.



Textbook question 7: 281.25 g of daughter material to 93.75 g of parent material. Note the loss of one proton per atom has not been considered in the calculation of this ratio.

Textbook question 9: Approximately three-eighths of a half-life has elapsed. Note that $^{40}_{38}\text{Sr}$ should be $^{87}_{38}\text{Sr}$. This is an error in the textbook.

Dividing 28 650 years by the half-life of 5730 years gives five half-lives: $\frac{24}{2} = 12$, $\frac{12}{2} = 6$, $\frac{6}{2} = 3$, $\frac{3}{2} = 1.5$, $\frac{1.5}{2} = 0.75$. Therefore, the amount of $^{14}_{6}\text{C}$ left is 0.75 grams.

9. Yes, all the $^{14}_{6}C$ will eventually disappear. However, it will take a long time before the last atom disappears.

10. $^{14}_{6}C$ would not be useful for dating basalt because that rock was never a living organism.

11. The geologic time scale gives an overall idea of what occurred over a certain amount of time. It is good for piecing together all the environmental and geological changes during a period of time to understand why or how they occurred.

Section 1: Follow-up Activities

Extra Help

1.

TYPE OF ROCK		CHARACTERISTICS			
		Grain/Crystal	Foliation	Colour	Other Characteristics
Igneous	Granite	large and coarse crystals, primarily quartz, feldspar, and mica	within individual crystals	generally pink, black, or white	the most common intrusive igneous rock
	Basalt	fine-grained	none	dark	the most common extrusive igneous rock
Sedimentary	Sandstone	made up of grains ranging from $\frac{1}{16}$ mm to 2 mm	none	light	small-grain sandstone, looks like fine sandpaper
	Shale	made up of particles that are less than 0.074 mm in size	none	varied	
	Limestone	formed from the shells of shallow-water animals	none	light	scratches easily
	Conglomerate	made up of particles with a wide range of sizes	none	varied	similar to broken-up concrete
Metamorphic	Marble	formed by recrystallized limestone	none	varied	
	Gneiss	coarse-grained, formed from granite that has metamorphised	yes	alternate streaks of dark and light material	have rough bands

2. You could not consider this to be a fossil because this is a "track" created in very recent time. It is not prehistoric. Maybe if the handprint is preserved into the far distant future, it might be considered a fossil by the being who discovers it.

3. a. iv. (principle of faunal succession)
   b. iii. (principle of original horizontality)
   c. v. (principle of cross-cutting relationships)
   d. ii. (principle of uniformitarianism)
   e. i. (principle of superposition)

4. **Textbook question 3:** Your definitions should be similar to the following:

- isotope – an element that has the same atomic number but different atomic mass
- radioisotope – an isotope that is radioactive
- radioactive decay – a process by which one element changes into another with the emission of radiation
- half-life – the amount of time it takes for one-half of the amount of a radioactive substance to decay
- parent material – the original material of a decaying radioactive substance
- daughter material – the product to which a radioactive substance changes
- decay curve – a graph showing the ratio of the amount of parent material to daughter material in the process of radioactive decay

5. a. 25%

b. $4.86 \times 10^{10} \times 3 = 14.58 \times 10^{10}$ years
$= 1.458 \times 10^{11}$ years

Enrichment

Your explorations in this Enrichment will be individual.

Section 2: Activity 1

1.

Era	Period	Epoch	Years Past (in millions)	Life-Forms and Major Events
Cenozoic	Quaternary	Halocene	0.01	• organized civilization by humans • animals that exist today were present
		Pleistocene	2	• ice age (glaciation, ice bergs) • wooly mamoths
	Tertiary	Pliocene	5	• splitting of the continents, earthquakes • fish were present in oceans • mostly grasslands
		Miocene	24	• volcanic activity • sabertooth tiger was present
		Oligocene	38	• tropical environment • tropical plants and ferns

Cenozoic	Tertiary	Eocene	55	• tropical environment • tropical plants • primitive horses were present
		Paleocene	66	• poplar-like trees • clams were present in oceans
Mesozoic	Cretaceous		144	• extinction of the dinosaur • tropical environment • the most known dinosaurs were present • fish were present in oceans • volcanic activity at the end of this period
	Jurassic		205	• volcanic activity near the beginning of this period • the first of the larger dinosaurs were present • tropical environment • flying creatures were present • large primitive fish and snails were present in oceans
	Triassic		245	• fern-like plants • tropical environment • primitive alligator-type animals present on land
Paleozoic	Permian		290	• volcanic activity • fern-type plants • insects present • first dinosaur present
	Carboniferous		360	• forests of poplar-like trees
	Devonian		405	• first vertebrates appear • primitive fish in oceans • leafless trees
	Silurian		435	• primitive fish toward the end of this period
	Ordovician		500	• primitive water animals present
	Cambrian		570	• some water animals
Pre-cambrian			4500	• some bacteria, amoeba, water animals close to end of era

There are few fossils from the Precambrian Era because most of the animals that were present were small and soft-bodied. Soft-bodies animals do not fossilize well because of the lack of a cartilage or bone structure. So much has happened on the Earth's surface since that distant time that most of the fossils created at that time have been destroyed through erosion, metamorphism, and so on.

Check the chart in the answer to question 1 in Section 2, Activity 1. The time lines indicated in Table E.3 may differ from what you have in your chart. This is because there are sometimes different opinions about when the major events occurred. The table may have helped you determine what some of the illustrations on Plate 2.1 meant.

a. Table E.3 has vertebrates appearing during the Cambrian Era. The chart has them appearing during the Ordovician Era. Table E.3 has major glaciation occurring during the Permian Era. The chart does not say anything about glaciation; it just says that major extinction occurred but the cause is not known. It may be that it was the glaciation that caused the extinction, but the two sources do not agree on this. Also, the chart says that Pangea came together in the Carboniferous Period, while the table says this occurred in the Permian. Much of the information in charts like these is based on theories. The theories vary both in content and time period.

b. These discrepancies indicate that there are differing ideas about the geological and environmental history of the Earth. The same information may be pieced together and interpreted in very different ways. Many pieces of information about the Earth's history are still to be discovered. This could be extended to say that the same thing holds true in any area of science. Facts may be interpreted in different ways until enough information is gathered to form a complete picture.

These are probably the most critical events:

- the formation of the Earth
- the formation of the crust, continents, and oceans
- appearance of the first life, leading to bacteria-like organisms and blue-green algae – this allowed photosynthesis to begin adding oxygen to the atmosphere
- formation of ozone begins
- oxygen-dependent life appears
- abundant life in the oceans
- sexual reproduction begins
- plants and animals move to land

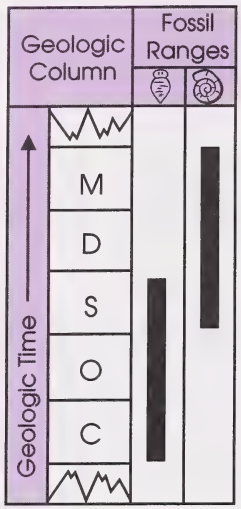
For each explanation you may have come up with suitable ideas that are not mentioned here.

a. Answers will vary. This explanation seems to be the most widely accepted. However, the sea also dropped (sometimes to lower levels) at other times and did not result in mass extinction.

b. Answers will vary. Pangea could have had drastic effects on some species, resulting in the extinction of some. However, the change to one continent occurred over a long period of time; the continents did not just slam together one day. If this continental change caused extinction, then there should have been more extinctions at other times when other land masses joined.

c. Answers will vary. Some sources say that glaciation occurred during the Permian Era. This could definitely have caused extinction of some species as plants and animals could not adapt to the colder temperatures. There are, however, many other cases of glaciation that are very well documented in the fossil record, and they did not seem to have caused mass extinctions.

7. and 8.



9. a. D, O, C b. D, S, C

10. Both regions are capped by Layer D. In Region 1, Layer D was affected by an igneous intrusion dated to have occurred 300 million years ago. Therefore, Layer D is older than 300 million years and so both Regions 4 and 5 are older than 300 million years. The layers below Layer D are older yet. From the diagram of Region 2, an igneous intrusion dated at 350 million years cuts across Layers O and S. Therefore, you know that earlier strata in Regions 4 and 5 are older than 350 million years.

11. Trilobite fossils are found in strata from between 570 million to about 250 million years ago.

12. The fossils of belemnites and trilobites could appear together in strata between about 340 to 250 million years ago.

13. The three fossils could appear in strata between about 340 and 280 million years ago.

14. A number of zone fossils gives a more accurate age than just one fossil. Note how in questions 10 to 13 the move from one fossil, the trilobite, to two and then three narrows down the geologic time span significantly.

15. a. Pelecypods and gastropods are most useful for correlating rocks of the Cenozoic Era, from 66 million years ago to the present.

    b. Nautiloids are most useful for correlating strata from 505 to about 450 million years ago.

16. A large number of fossils of an organism that were present only for a short time are most useful for accurate dating. The age of the strata containing those fossils can be accurately pinpointed. Organisms that existed over long stretches of time are often not that useful, for they are present in the strata from many periods.

17. Sea organisms provide the best zone fossils because most of them have hard exterior shells that do not decompose over time. Their soft body parts may decompose, but the hard exterior shell remains. They were very numerous and thus produced many fossils. Seas and oceans extend around the world, allowing for organisms to spread around the globe, and so making their fossil remains very widespread. This makes them ideal for correlating strata from different areas around the world.

18. It is difficult to judge which article gives more "hard" facts. The first contains much more information, but it also is much more sensationalistic, written in the style of a feature story rather than an pure objective news story. There are also some facts which are in error, yet it does a good job of detailing Hildebrand's scientific search for evidence. The second article is short, but to the point. It does not sensationalize and states the theory of a panel of experts, based on fossil evidence of extinction occurring over time, not as the result of one catastrophic event. It does not, however, give much of the evidence on which the theory is based.

19. These are the major steps through which Hildebrand tried to prove his theory:

- began researching the iridium layer (1984)
- discovered jumble of rock debris, seemingly caused by an event that carried the debris a long distance (1988)
- visited more than 60 sites looking for the crater around the Caribbean
- found ejecta layer in Haiti – clay, tektites, and so on
- applied for job, saw map of gravitational fields on wall – showed an anomaly over the Yucatan
- crater impact under village of Chicxulub

20. a. In Section 1 you learned that Carbon 14 dating is only accurate to around 40 thousand years ago, although it is used to date items up to 70 000 years. There is absolutely no way Carbon dating could be used to measure anything 65 million years.

b. The accuracy of media may sometimes be suspect, especially when it comes to scientific information. Reporters and editors may not have enough knowledge to judge whether a fact is accurate or whether a theory is reasonable. Sometimes the media may sensationalize in order to sell papers or magazines or to increase numbers of listeners or viewers.

21. In the scientific process, a person proposes a hypothesis to explain some phenomena. The hypothesis is based on available evidence and logic. Evidence is then sought to support the hypothesis. In the first news story, Hildebrand put forth the hypothesis that a meteor's impact with Earth is what led to the extinction of the dinosaurs. This was based on the knowledge of the iridium layer in strata marking the period when the dinosaurs disappeared, and knowledge about the effects of dust and other factors on the environment. He set about to find where the impact crater might be located and found evidence that it exists in the Yucatan Peninsula. The hypothesis is then formally presented to the scientific community where it is scrutinized in detail. Often the new hypothesis is rejected because there is not enough hard evidence to support it beyond any doubt. This is shown in the second article with the American Geological Association rejecting Hildebrand' hypothesis, and suggesting the Pele theory as a more likely explanation for the extinction. The ideas are now public, though, and scientists around the world will begin looking for more evidence to either refute or support the hypothesis. With the accumulation of evidence, the hypothesis may either gradually gain acceptance or be rejected by the establishment.

22. Answers will vary. Your explanation for the extinction of the dinosaurs may take any form, as long as the known processes that could lead to negatively affecting life-forms and the environment play some role in the explanation. Many suggestions have been made as to possible events that added to the extinction. Among them are the following:

- climate change, either heating up or cooling down
- change in habitat
- competition with other species, like mammals
- volcanic activity – poison gases, dust
- unusual viruses or bacteria
- increase in solar radiation
- asteroid or meteorite impact

There are many aspects you may have explored in encyclopedias, science texts, material from paleontological museums, guides to fossils classification, information from the Canadian Geological Survey, and so on. You should support your hypothesis with some evidence.

23. The following are the movements mentioned in the table:

- Europe separates from Greenland
- Australia drifts north of Antarctica
- India joins with Asia
- Red Sea opens up
- Sierra Nevada mountains form
- Gulf of California opens up
- Africa drifts to close Strait of Gibraltar
- Panama joins North and South America

24. The major developments in life-forms were the extinction of the dinosaurs and the appearance and evolution of modern mammals. Primitive humans also appeared during this era and evolved to modern humans. Around 7000 years ago the first human agricultural society was recognized.

25. There were a number of climatic changes during the Cenozoic Era. At first the climate was warm. About 11 million years ago the climate became more dry and temperate, evidenced by grasslands becoming more dominant as compared with forests. Then, about 2 000 000 years ago, an ice age began to set in. The ice ages ended about 11 000 years ago. The climate warmed up and stayed relatively the same as it is now.

26. There are few rocks of the Cenozoic age because most of the rock sediment of the Cenozoic age is recently deposited and still close to or at the surface of the Earth and has not yet gone through lithification.

27. Right now climatic changes are beginning to occur as a result of the greenhouse effect. If this continues, the climatic changes will also alter life as it is now. Also, there has been a great deal of movement of the tectonic plates and some volcanic activity. If this movement and volcanic activity continues, it will likely also have some effect on life as it is now. Asteroids or meteorites could strike the Earth. And in the past many ice ages came and went. A new ice age could return. Also, today, humans are faced with a dangerous decaying of the ozone layer. This could seriously damage both plants and animals, possibly leading to mass extinctions. These are the kinds of changes that have brought on the greatest changes in the past, so it is likely these are changes that will bring an end to the Cenozoic Era.

28. a. The climate was desert when the ankylosaurs died. This is indicated by the petrified sand dune.

    b. The five baby ankylosaurs could have been in a nest. This would explain why they were so close together. They could also have been huddling there for protection from a storm. Another possibility is that they died in separate locations and were washed to that site, maybe a sand dune at a bend in a river.

    c. Because multiple dinosaurs were found at other sites, it suggests that these animals could have lived in herds or families.

Section 2: Activity 2

1. Your answers to textbook questions 1 to 4 will vary depending on the fossil samples you may have worked with. You will have used reference books to identify your fossil. They will have provided you with information about where those particular fossils have been found around the world and the types and ages of strata in which they have been found. The references also may have provided you with information about the environments when the organisms were alive.

2. Your answer will vary depending on which fossils you worked with from the collection. Check the answer for question 1 for more detail.

3. Your sketches should clearly show the distinctive shape of the fossil, any segments or body divisions and structures visible, and the texture of the fossil if possible.

    a. Photograph 4

        - In your sketch show and label the spiral shape. Identify the shell-like appearance.

b. Photograph 5

- Your sketch should include the pine cone as well as what appears to be part of a small branch. Label each.
- The individual layers and similarity to today's pine cones are the identifying features.

c. Photograph 6

- Your sketch should include the long ribbed stem. This is one of the identifying features.
- The fossil on the right is similar to the one on the left but has opened up.

4. a. Photograph 4 – The fossil is an ammonite identified by the spiral shape and the shell-like appearance.

b. Photograph 5 – The fossil is a pinecone and part of a branch. The individual seed layers help to identify the pinecone.

c. Photograph 6 – The fossil is a crinoid. The long ribbed stem and the filament-like flower help identify this fossil.

5. The Royal Tyrrell Museum of Palaeontology collects and displays all types of fossils and is especially known for its dinosaur collection, the largest in the world. The museum is also a major research facility, conducting research in paleontology in Alberta and internationally.

6. a. The major areas of research include the following:

- the dinosaur-bearing strata of Alberta
- Paleozoic invertebrates of Alberta, BC, the Arctic, and Australia
- the Dinosaur Project
- Triassic outcrops in northeastern BC which yield excellent fish and reptile fossils

b. Your answers will be personal, depending on your interests.

7. The Dinosaur Project is a joint research initiative of the Royal Tyrrell and Chinese paleontologists. They have shared research, conducted digs in the Gobi Desert, and made some exciting joint discoveries including new species of dinosaurs and reptiles and new information about dinosaur behaviours.

8. Studying fossils from around the world gives scientists more complete information about the global climate, the mapping of land and seas at particular times, and comparing fossils to see relationships among fossil species to further piece together the evolutionary paths of life.

9. The fossil and its strata provide joint information, allowing the strata to be correlated with worldwide formations, and showing the situations/conditions under which the strata was deposited, and, thus, the conditions under which the organism lived. The strata can help identify the fossil.

10. China received large amounts of money in order to continue research, and the Chinese scientists were able to study with the Alberta scientists, world-renowned paleontologists. Alberta's team had the chance to explore and collect in rich fossil beds that had not been studied since the 1930s.

11. This area was a wide floodplain of a major river. The floodplain supported luxuriant plant growth, which in turn supported a rich ecosystem.

12. If the dinosaurs were related, how did they develop in such far apart areas? Were the continents connected? Did the dinosaurs migrate back and forth across a land bridge? Or did the dinosaurs on each continent develop independently and just coincidentally develop similar traits?

13. Not finding anything at all, as far as a fossil goes, shows that a particular fossil was probably not present in the area when that strata was being deposited. Knowing that a strata lacks a particular fossil is still important in correlating that strata.

14. a. Finding the second group of ankylosaurs suggests that the congregation of a number of young was not an accident. It begins to show a pattern – perhaps it was a nest, or the ankylosaurs travelled in herds or flocks. It suggests the dinosaurs exhibited social behaviour.

    b. Dinosaurs were previously thought to exhibit definite reptile behaviour, being very solitary and antisocial.

15. a. The climate in the area of the dig at the time the fossils were laid down was semiarid to arid, with some seasonal rain and strong winds. The groundwater seems to have been adequate to promote some lush plant growth.

    b. Alberta at that time was subtropical to warm temperate, at times similar to today's Georgia and South Carolina. There was adequate seasonal rainfall, with the land made up of swamps, estuaries, and sea coasts.

16. If the environments of the two areas were so different, why do the dinosaurs seem so alike? There also is the difficulty of dating the Campian strata. In most of science, when a new piece of evidence is found, it may answer some questions, but raise many others.

17. Answers will vary depending on your interests. One of the positive aspects of a career in paleontology would be the excitement of a dig and the discovery of new fossils. One negative aspect is the few positions available in museums.

Section 2: Activity 3

1. a. All but a small area in northwestern Alberta was under sea water, with most of the eastern half and southern third shallow seas supporting reef formations.

    b. Alberta was covered in shallow seas in the Late Devonian. The sea level increased in the Early Carboniferous so most of Alberta was covered in deeper water. By the Later Carboniferous, the eastern portion of the province rose so that only the western edge of Alberta was covered by water.

    c. The Later Carboniferous would most likely have been a period of erosion as most of the province was exposed land.

    d. The Middle Devonian, and especially the Late Devonian would provide the richest source of oil, as the province was covered by reefs during those periods.

    e. The Early Carboniferous Period would have deposited limestone, sandstone, and shale strata as the province then was covered by deeper water in which organisms with shells would have lived to create the limestone, and into which sand and clay would have been deposited to create sandstone in the shallower areas close to the shore and shale in the deeper areas.

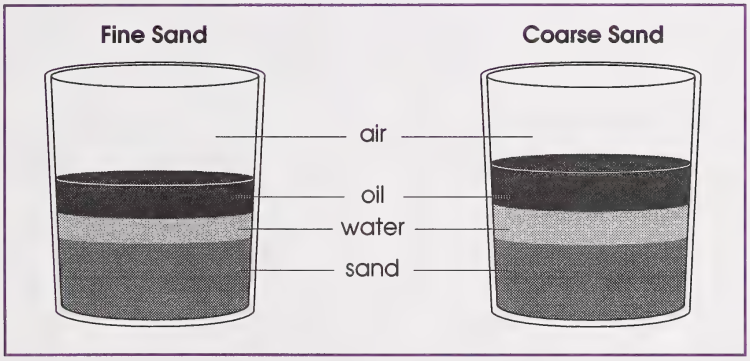
    f. The Later Carboniferous Period was the only period of the four maps which showed much land mass present in Alberta. This was a period of massive swamps and forests.

2. Your results may be something like this. These measurements were made with 1-L jars. Actual measurements will vary with the size and shape of jars and the size of the grains of sand.

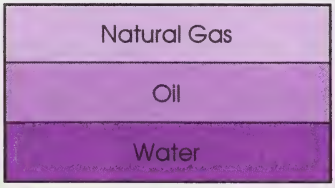
Time	Jar with Fine Sand	Jar with Coarse Sand
5 minutes	0.5 cm of water 0.5 cm of oil	0.5 cm of water 1.5 cm of oil
30 minutes	0.8 cm of water 0.8 cm of oil	1.0 cm of water 1.6 cm of oil
1 hour	0.8 cm of water 0.8 cm of oil	1.0 cm of water 1.7 cm of oil
5 hours	0.8 cm of water 1.0 cm of oil	1.0 cm of water 1.8 cm of oil
1 day	0.8 cm of water 1.2 cm of oil	1.2 cm of water 1.8 cm of oil
3 days	0.8 cm of water 1.5 cm of oil	1.3 cm of water 1.8 cm of oil

3. The amount of oil above the sand was greater in the jar with the coarse sand after 5 minutes. The amount of water above the sand was about the same in each jar. The amount of oil and water above the sand increased more quickly over time in the jar with the coarse sand. After 3 days the jar with the coarse material had more oil and water above the sand than the jar with the fine sand.

4. Your layers may vary somewhat, but will probably look somewhat like these.



5. The natural gas, oil, and water will arrange themselves in this order:



6. a. 1.00 – **water** 0.67 – **natural gas** 0.92 – **oil**

   b. In the layers in the experiment, water made up the bottom layer; so it is the heaviest of the three, and so would have the specific density of 1.00. The oil was in the middle; so its specific density would be the 0.92. The air (natural gas) is the lightest; so it would have the lightest specific density, 0.67.

7. Coarse material would exhibit the most porosity. The materials moved quickest through the coarse material to form differentiated layers. The next question also exhibits why the coarse material has the greatest porosity.

8. a. The coarse material released the most oil and water.

   b. The fine sand released less oil. The fine sand packs more tightly together, thus creating more surface area for the oil and water to cling to.

   c. Some liquids are retained by materials with less porosity. Liquid would move more easily through coarse materials than it would through fine materials.

9. The oil company would most likely choose to drill in an area where the sandstone is made up of coarse particles because the oil is easier to collect since it flows more freely through the coarse materials.

10. The materials are listed from fastest to slowest in allowing materials to flow through them.

    gravel, sand, sandstone, limestone, shale, slate, granite

11.

Layer of Strata	Porosity	Well A	Well B	Well C	Well D
I: shale	3%	surface	surface	surface	surface
II: sandstone	15%	absent	650	675	600
III: shale	3%	550	510	550	490
IV: sandstone	12%	275	absent	250	250
V: shale	3%	100	225	115	125

Note: Answers within ±10 m are acceptable.

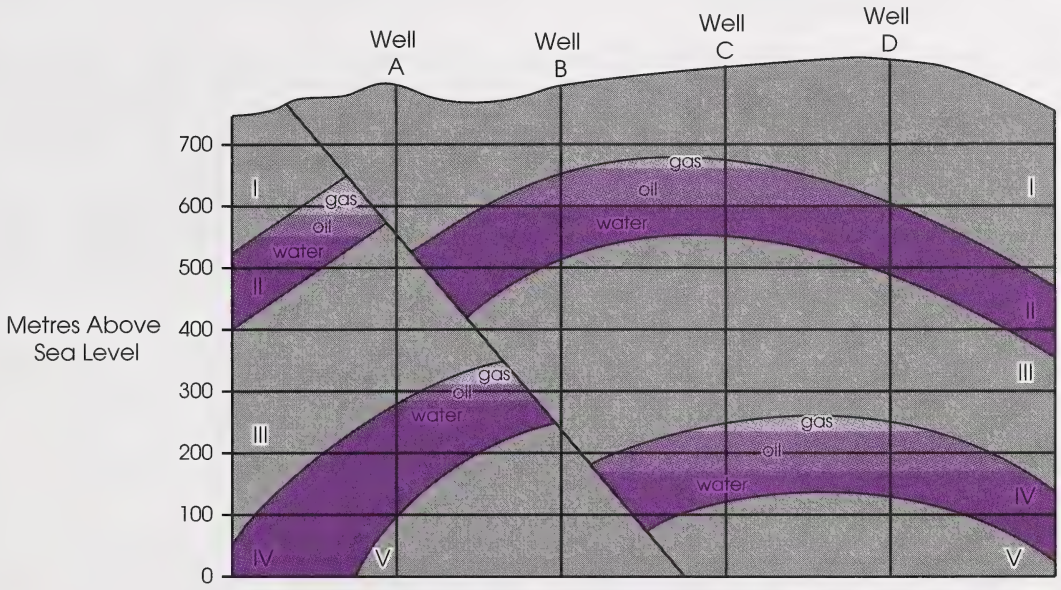
12. Well C will be the most likely well to hit oil or gas. It is drilled at the apex of an anticline in which sandstone strata is capped with a layer of shale. This is a common oil reservoir formation.

13. An anticline formation and a fault formation are present.

14. a. They would be called reservoir rocks. b. These are referred to as cap rocks.

15. a. Well C hit natural gas at the very top of the anticline, where the gas collected above the heavier oil. Well B hit Layer II a few metres lower than Well C. At that point oil was located, but that point in the layer was to the side of the natural gas band. Well D hit Layer II even lower, at 600 m. That depth was below and to the side of the gas and oil layers.

b. The following diagram illustrates possible gas, oil, and water locations in Layer II and Layer IV. The question required an answer for Layer II only.



16. The strata is at a slant and Well A hit the strata below the depth where oil and gas were located, but hit the heavier water layer below them.

17. Well C will probably be the best producer of natural gas because it hits two reservoir layers (Layers II and IV) at the top of the anticlines where the natural gas will collect.

18. Well C will also probably be the best producer of oil as it cuts through the oil-bearing Layers II and IV. Well B hits oil in Layer II, and may produce very well. Well D hit water in Layer II, but may hit a good oil deposit in Layer IV.

19. $$\frac{6.6 \text{ billion in reserve}}{327 \text{ million per year}} = 20 \text{ years}$$

At current production, our reserves will last approximately 20 years.

20. a. Coal is no longer used extensively as a fuel because of the widespread use of natural gas as a major fuel. Natural gas being cleaner and easier to produce and transport. Oil and other petroleum products also replaced coal for heating, chemicals, and in the production of other products.

b. Major electric projects have been built close to coal deposits – for example, at Sheerness and at Wabamun. Higher grades of coal are also exported to Japan and other countries for use in industry.

c. Answers will vary. Take a position and find supporting evidence. You might include ideas on how there are countries that are increasing the use of coal in industry. There is renewed use of coal in Alberta, for example, at the Genesee Power Plant near Edmonton. However, you might point out that unless most of the pollutants can be removed, pressure to reduce the use of coal may be brought on by groups who feel the atmosphere is being polluted.

21. The future revenues for oil and gas will likely be cyclic. Alberta is suddenly caught in an oil "boom" again, where a few years ago, the oil market was almost non-existent. The Middle East still has vast reserves; so a shortage in the near future is unlikely. Reserves of fossil fuels are limited; so sometime in the future fossil fuels will become very valuable.

22. Alberta's energy future probably lies in synthetic crude oil and coal. Synthetic crude oil will be able to be produced for a long period of time after reserves of conventional crude are depleted and shortages have driven the price of petroleum up. Alberta also has plenty of natural gas reserves, which are not likely to run out for a very long time. At this point coal is still not considered to be as valuable as petroleum fuels, but with the large reserves Alberta has it is likely to become important in the future.

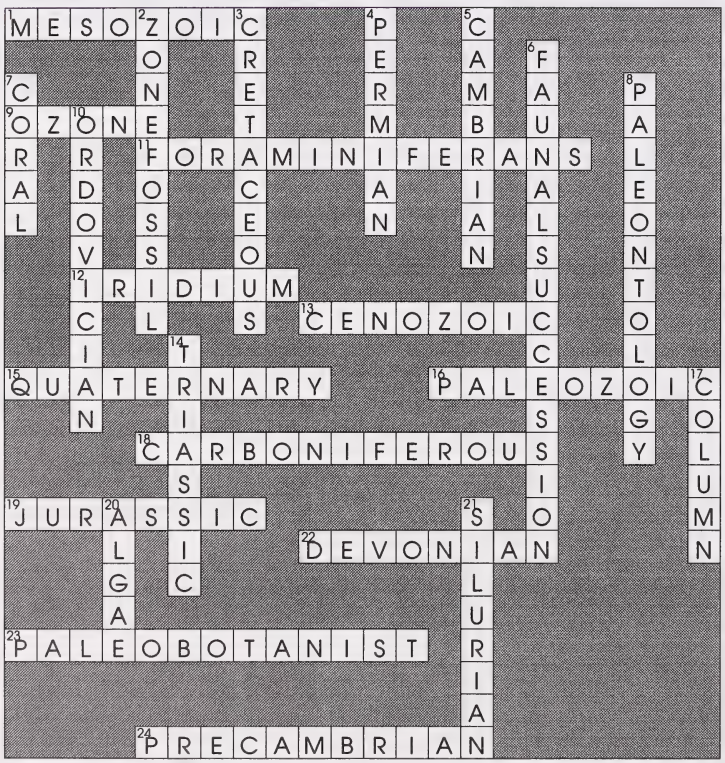
23. a. Answers will vary. Use your imagination, coupled with knowledge of new scientific techniques, or techniques and processes that are yet to be discovered or developed. A couple of ideas are given. In the future there may be some way of doing some sort of aerial scan that will identify the positions of oil and gas reservoirs. Better seismic techniques may be developed.

b. Answers will vary. It would be helpful if there was a chemical which could pull the oil out of very dense rock and enable it to be recovered quickly. There have been discussions of using the heat of nuclear reactions to liquefy heavy oil. Maybe in the future nuclear fusion could be used.

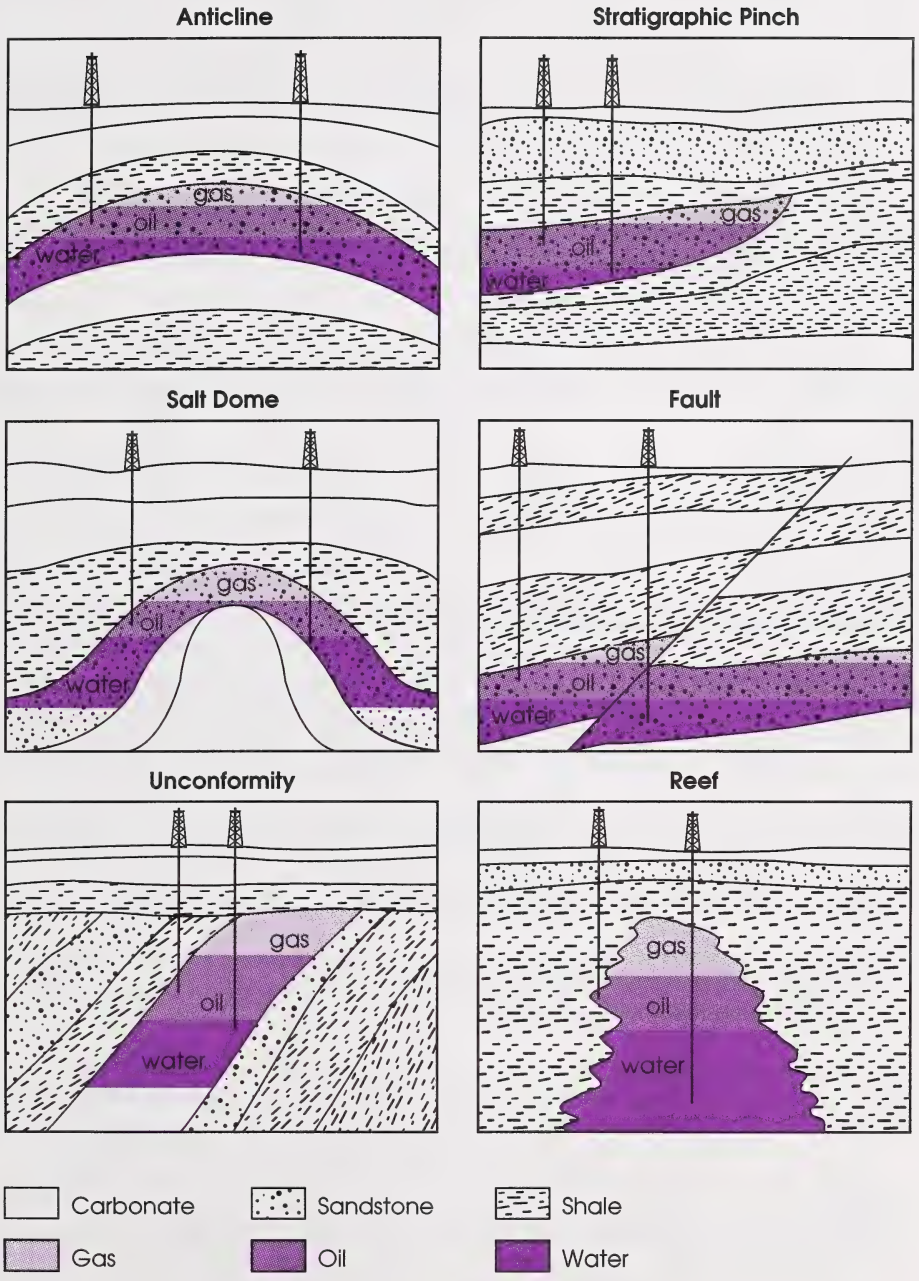
Section 2: Follow-Up Activities

Extra Help

1.



2. a. You should have drawn any two of the following reservoirs.



b. Layers of natural gas, oil, and water are shown in each of the previous reservoirs. The thicknesses of your layers may vary, but the relative order of the layers should be the same, with the natural gas (lightest) as the top layer and the water (heaviest) as the bottom layer.

c. and d. Sample wells are shown in each reservoir with one hitting oil first and the other hitting gas, then oil, then water. The positions of your wells will vary according to where your layers of natural gas, oil, and water are located.

Enrichment

These are research and video activities. You may use some of the resources mentioned earlier in the module and check out your local library for useful books, magazines, newspapers, and videos.

Section 3: Activity 1

1. You may have some variation to this ordering, but the events must be ordered so that the cause-and effect relationship is clear and logical. One event sets up conditions which allow the next event to occur.

a. **10**	d. 8	g. 9	j. 2	m. 13
b. 6	e. **1**	h. 14	k. 7	n. 4
c. 3	f. 11	i. 5	l. 12	

2. a. The sun was responsible for driving photosynthesis in the first photosynthetic plants. As photosynthesis continued oxygen was produced.

   b. The most basic effect the sun has had on the development of life is providing the light energy for our planet to be able to support life. As the sun drove the photosynthesis that supported plants, it also produced the atmospheric oxygen that allowed animal life to develop. Of course, the sun continues to provide the energy which runs most of the Earth's processes upon which all life depends.

   c. The movement of the tectonic plates helps to drive the rock cycle. When the plates separate, magma from the mantle is allowed to rise up towards the surface and add new rock to the Earth's crust. Where the plate slides under the other plate, the layer is forced down and melt to magma. The collision of plates leads to the uplifting of land, earthquakes, and episodes of mountain building.

   d. The movement of the tectonic plates resulted in volcanic activity which released carbon dioxide and nitrogen into the atmosphere. The photosynthesizing plants used the carbon dioxide in the photosynthesis process and produced oxygen.

   e. The early atmosphere was made up of carbon dioxide, nitrogen gases, and some others, but very little oxygen. This allowed organic compounds to collect in the seas without oxidizing. This organic chemical "soup" is possibly what the first simple life-forms developed from. Once photosynthesis began, the oxygen levels increased and animals developed. The oxygen became abundant enough to allow for the creation of the ozone layer which could protect life from harmful ultraviolet radiation and allow living things to evolve into forms that could live at the surface of the sea and gradually move on to land. The amounts of carbon dioxide and oxygen have fluctuated through history, affecting climate and life-forms as it did. Changes in our atmosphere at present – the increase in carbon dioxide and the destruction of the ozone layer – could both have major consequences for life on Earth.

f. Plants have had a significant effect on the atmosphere, using carbon dioxide and releasing oxygen. Over the course of history, plants have helped to maintain a balance of carbon dioxide and oxygen in the atmosphere. Since the beginning of the industrial age, humans have been constantly polluting the atmosphere. The pollution from the burning of fossil fuels, industrial pollution, and vehicle exhaust all contribute chemicals which decrease the quality of the atmosphere. Trees and other plants do help filter out some pollutants, but overall the amount of pollution in the atmosphere has been increasing. The burning of fossil fuels has increased the carbon dioxide levels dramatically, and could lead to global warming. The ozone destruction is also the result of Earth's life-forms affecting the atmosphere.

g. The movement of the tectonic plates allowed the release of carbon dioxide through volcanoes. The carbon dioxide in the atmosphere was used by the photosynthetic plants to produce oxygen. The presence of oxygen in the atmosphere allowed the development of complex life-forms.

3. Humans have become more technologically advanced and more industrialized over the course of history. Unfortunately, these technologies and industries create pollution as a by-product. As the pollution levels in the atmosphere increase, the quality of the atmosphere is decreased. Burning of fossil fuels has created rapidly increasing levels of carbon dioxide which many scientists suggest will lead to global warming. Chemicals such as CFCs are causing the depletion of the ozone layer.

4. You may have come up with any number of possible causes. Two possibilities are mentioned here. The Little Ice Age could have just been one of the colder swings in Earth's climate cycle. It seems fluctuations in temperature have been a normal occurrence in Earth's history. The second possibility is that major volcanic eruptions may have put huge amounts of dust into the atmosphere which may have blocked out some of the sun's rays and caused a reduction in temperatures.

5. a. The climate change wiped out the beech population. Without the beech trees, other trees, especially white pine, oak, and birch, began to dominate the forests.

b. The change in the forest meant that dead trees were either decomposing or burning, releasing various carbon compounds into the atmosphere. The mass of the replacement trees was significantly less than the original beech, so less carbon dioxide was being fixed, allowing the CO_2 to accumulate.

c. The extra carbon dioxide in the atmosphere contributed to the global warming that increased the temperature of the Earth and brought the end of the mini ice age.

d. The increase in the temperature will likely allow some types of tree to grow better, while it may cause other types to disappear.

e. The climate change affected one of the economic focuses of Ontario. The presence of the large white pine forests made them a cornerstone of the economy – lumbering and pulp and paper. The other hardwoods like oak are also economically valuable.

6. If humans destroy the rainforests, serious climatic changes could occur. The amount of carbon dioxide in the atmosphere would increase, adding to global warming. The climate change could be very beneficial for some aspects of life, but others aspects could be severely affected. A climatic change could lead to the extinctions of plants, animals, and possibly even the human species.

7. The culling of dead and dying trees would cut back on the amount of greenhouse gases being released into the atmosphere. This should help to slow down the process of global warming. However, the question remains – what would be done with the culled trees?

8. Ash, hickory, and elm seemed least affected by the Little Ice Age.

9. Hemlock looks to have been adversely affected as well.

10. The number of elm was severely reduced in the 1900s. Most of the elm in Ontario were wiped out by Dutch Elm disease.

Section 3: Activity 2

1. Your knowledge of genetics tells you that characteristics that can be passed on to the offspring are controlled by the genes in the DNA. Only an alteration in a gene can cause an alteration to the characteristics of the offspring. No matter what one may do to change his or her body characteristics, those traits do not make changes in the genetic material in the sex cells, and the traits will not be passed on to the offspring. Exposure to radiation and ingesting some types of drugs may cause chromosomes to be damaged and cause mutations in offspring, but these are not acquired characteristics as discussed here.

2. Answers will vary. Here is one proposal to test the idea. You could have suggested that the theory of use and disuse be tested by not allowing a test specimen to use one limb on its body. You would have to wait to see if the next generations are born with or without the particular limb to prove or disprove the theory. It is not likely that the future generations would be born without a limb. The children of human amputees are not born without the limb that their parent is missing.

3. a. The needles protect the cactus from animals which would eat it.

   b. The position of the photosynthesizing cells eliminates the need for leaves. This conserves water that would quickly evaporate in the desert environment.

   c. The change in the colour of a rabbit's fur enables it to blend in with its surroundings in the different seasons of the year. This hides it from its predators.

   d. Infrared sensors on a snake's face enables it to sense when prey is near when its visual sense may be inhibited by darkness or when its eyes are cloudy at shedding time.

   e. A tiger's stripes help it blend in with the grass and trees in its environment. This hides it from the prey that it is stalking.

   f. Wolves live in an organized pack to increase the efficiency of the hunt. If a wolf was to hunt on its own, it would probably die of starvation because it would have difficulty catching large prey on its own. The pack works together to surround the prey, wear it down, and finally bring it down.

4. Answers will vary. A sample answer is given. Many insects have the appearance of a leaf or branch to help them hide in their surroundings, thus protecting them from their predators.

5. Lamarck would say that as a giraffe stretched its neck to reach leaves in the branches its neck grew a bit longer. This acquired characteristic was passed on to the next generation, which was born with slightly longer necks. As the offspring also stretched their necks to reach higher leaves, they acquired even longer necks. This trait of longer necks would be passed on to the next generation. Over many generations of stretching their necks, giraffes finally reached the stage where their necks were long enough to reach the leaves easily so they would no longer have to stretch. This would stop their necks from growing any longer.

   Darwin would say that only the giraffes with the longest necks in the giraffe population would survive because they could reach a food source that the ones with shorter necks could not reach. The survivors would then have offspring that would carry the genes for longer necks. These offspring would again be the most successful, especially the ones with the longest necks. Over the generations the trait of longer necks would be naturally selected, and the traits would become common across the giraffe population.

6. Between 1848 and 1898 rapid industrialization occurred and produced soot that darkened the tree bark of the trees the moths lived on.

7. The moths not recaptured were most likely killed, probably as the prey of insect-eating birds.

8. In the first experiment, the majority of the moths that were recaptured were the peppered form. At this time the tree bark was still light-coloured and so the peppered moths were camouflaged, protecting them from their predators. The dark-coloured moths were not camouflaged and were easy for the birds to see and catch. Thus, their survival rate was not as high.

   In the second experiment, the dark-coloured moths survived the best because the trees had been darkened by the soot and the dark-coloured moths were camouflaged. The peppered moths were easy for the birds to see, and so they were killed off quickly.

9. The change in the colour of the tree bark that was caused by heavy industrialization stimulated the changes to the colour of the moths between 1848 and 1898. In this case the darker moths that blended in with their surroundings had a much better chance of survival than the moths that were not camouflaged. The trait of dark colour was thus naturally selected and became more common in the population.

10. Answers will vary. You may have used a different example or no example. Natural selection and some type of physical isolation of the breeding populations are the main processes that led to different species developing. Evidence of separate species developing from common ancestors has been well documented. An example can more easily show how the processes operate. Two separate but very closely related species of squirrel live on opposite sides of the Grand Canyon. It is believed that they had a common ancestor. As the Colorado River deepened and widened its canyon, the population was split and isolated, some on the north side and some on the south. With the populations isolated, they became separate breeding pools. The climate on the north side of the canyon is colder and the rocks are darker. Traits were naturally selected to make the breeding pool at the north more successful in their environment. The members of the population that had darker fur would be able to hide more easily in the rocks and so would form the majority of the breeding population. Over time the separate population on the north side of the canyon came to have dark fur. Other traits also were selected over time so that the squirrels on the north side became so different from those on the south that they could no longer even breed with each other. They, at that point, became separate species. So it was with the development of all other life-forms. Geographical isolation led to separate gene pools which then took off on their own developmental path, subject to the process of natural selection. This will be covered in more detail in the upcoming material.

11. At first there was only the one species of finch in the Galapagos. Somehow some of the birds were carried to other islands, possibly through a storm. The stranded birds had to adapt to their new surroundings and the ones that didn't were eliminated through natural selection. The traits that allowed them to successfully compete in different environmental niches were traits that survived in each separate breeding population. Over a period of time the adaptations changed each group of birds enough that they could no longer breed with the original species or the other isolated groups on other islands. At that point they were separate species.

12. The primates branched off at about the beginning of the Paleocence epoch (Tertiary Period), about 65 million years ago.

13. The therapsid is shown as the ancestor to all mammals.

14. Most monotremes, such as the duck-billed platypus, lay eggs, have unusual features like bills, and excrete milk through scaly areas rather than through defined mammary glands as in other mammals.

15. Uintatheres, which became extinct at the end of the Paleocene, and Amblypods, which disappeared in the middle of the Oligocene, are extinct members of the Elephant branch.

16. The branch containing the sloths branched off at the end of the Jurassic. The carnivores branched off at the end of the Cretaceous, just before the primates took their route. The diagram thus suggests that the monkey, a primate, is more closely related to the tiger, a carnivore, than to the sloth.

17. The diagram shows the therapsid, an ancestral mammal, to have existed at the beginning of the Triassic Period, which began approximately 225 million years ago. Since some of the evolution was in recent times, the length of time for the change is 225 million years.

18. The straight line suggests that the insectivores are descended most directly from the therapsids.

19. Forests were replaced with grasslands. The horse no longer needed to eat leaves off trees, so its teeth adapted to better suit grazing for grass. The grassland also provided the horse new terrain to move over. Its legs became longer and its feet were changed to accommodate running quickly over flat and open terrain.

20. Only the horses that were able to adapt to the new surroundings were selected to survive. The hooved feet and the longer legs were positive traits that would enhance survival on the grassland. The horses with those traits survived and passed their survival traits on to their offspring. Over time the horse developed into the modern form you know today.

21. The tree shrew is considered to be the common ancestor of the primates.

22. The demand for good eyesight led to the development of stereoscopic and colour vision. The need for good muscular-nerve coordination led to the development of the large primate brain. Another development of the primates is the thumb, which is useful for grasping objects.

23. a. The gorilla is closest.

    b. The branches separated in the early Miocene, approximately 24 million years ago.

24. You can explain this in terms of the development of new species as discussed earlier in this activity. Humans and apes had a common ancestor, but each diverged and developed on its own evolutionary path. Humans did not descend from apes, just as apes did not descend from humans.

Secton 3: Activity 3

1. a. Charles Darwin observed giant tortoises, many different species of finches, scarlet crabs, red-footed boobies, and marine iguanas. He observed that species far apart geographically showed more differences than those that were located nearer to each other. Darwin filled many notebooks with complete descriptions and drawings of the plants and animals he encountered on the voyage.

   b. These observations raised the question of why so many different species of finches had evolved on the small isolated Galapagos Islands. He also wondered why there were so many other species of animals that occurred nowhere else on Earth. Why geographical distance correlated with increasing differences among species also puzzled him.

2. Darwin's idea of the survival of the fittest was based on the notion that the Earth's resources are limited and the population of a species is always so high as to create competition for survival. Only those organisms best suited for survival (for example, in getting food or avoiding predators) will prevail to produce offspring. The new generation will inherit the traits that made the parents successful. The next generation will go through the same selection process, with only the fittest surviving. As each generation passes, the species can become better and better suited for survival. Over time the new generations may become so different from the original ancestor that they can be considered a new species.

3. As the science of genetics becomes more advanced, many ethical debates come up. Now that geneticists have the ability to clone organisms and to genetically alter or control the human genetic code, many public groups and theologians are concerned about the questions of creation that are being raised. Is it ethically correct to create organisms whose entire genotype is controlled, especially human beings? Is it right to be able to clone any human being or other organism on the Earth? Should the technologies be used to choose the sex of a child? Should fetal tissue be used for implanting into others? Should sixty-year-old women be implanted with fertilized eggs and given hormone therapy so they can deliver a child? Should human embryos be genetically engineered to produce only super intelligent children? or super athletes? or people with absolutely no oddities or abnormalities? Some people see these advances as being useful ways of controlling human populations or making human existence happier. Others fear what could happen if the technologies are used for evil. Do you have particular views about these issues?

4. The fossil record has shown that in many cases it has taken millions of years for some species to have developed to their modern forms. Absolute dating has shown the age of the earliest fossils to be billions of years old. The new knowledge of genetics also shows that genetic changes cannot naturally occur "overnight." Natural selection is a slow process, taking millions of years for new species to differentiate themselves from common ancestors.

5. If you look at the fossil record of shells, there sometimes doesn't appear to be much gradualism between the different shells in different layers. There appear to be abrupt changes in the shapes of shells. There are many gaps in the fossil record that seem to be key "missing links" in the development of many organisms. There are many cases of mass extinctions where many species abruptly disappear from the fossil record, and are then rapidly replaced by many entirely new species. This shows that not all changes occurred in a gradual manner.

6. a. The theory of punctuated equilibrium says that instead of species changing gradually over long periods of time, species often change suddenly after long periods of remaining the same. Appearances of new organisms in the fossil record frequently occur suddenly and in unusual groupings.

   b. The theory of punctuated equilibrium differs from gradualism in that evolution occurs in "fits and starts," rather than in an orderly gradual manner. There are long periods that exhibit very minor evolutionary changes, and then periods of relatively short geologic time in which rapid evolutionary change occurs.

   c. The theory of punctuated equilibrium offers explanations for the sudden emergence of species that appear to be completely different than all other species. It accounts for the long periods of little change and the short periods of rapid evolutionary change.

   d. This theory still has Darwin's basic ideas of evolution as its basis; it is just the time frame over which evolution occurs and some of the ways in which evolution occurs that is different from the theory of gradualism. The ideas of survival of the fittest and natural selection still form the basis of the theory.

7. a. Some of the geologic changes that could have served as a stimulant to periods of rapid evolution could be seas drying, land being uplifted, rapid climate change, and volcanism.

   b. If geologic changes cause immediate changes to the terrain or to the climate or environment, an organism does not have time to gradually evolve to suit its new surroundings. If it doesn't change immediately, the extinction of that species results. Either the organism must have radical traits that allow it to survive and pass its traits to a new population while others become extinct, or it has traits that allow it to successfully fill the environmental niche left by the extinct species.

Section 3: Follow-up Activities

Extra Help

1. a. Lamarck would say that the carnivore's sharp teeth came through usage. The ancestors caught prey and, through chewing on the meat, developed sharp flesh-tearing teeth. This trait was then passed on to the offspring. They, too, added to this trait by chewing on flesh, thus making their teeth even sharper. The traits for these sharper teeth were then passed on to the next generation. This went on generation after generation until the carnivore's teeth were sharp enough that no further development along that line was needed.

   b. Darwin would say that the trait for sharper teeth was already present in some members of the population. The sharper teeth gave the advantage for survival to those members of the population, for they could catch and devour their prey more easily. This edge made them the survivors in the survival of the fittest, and members with those traits were the ones who survived to breed. Thus, the trait of sharper teeth was passed on throughout the breeding pool. The offspring with the sharpest teeth were also naturally selected and formed the surviving breeders for the next generation. Therefore, the trait of longer, sharper teeth became established throughout the population.

2. The chimpanzee and the gorilla had one common ancestor primate. Somehow the ancestor population was isolated into two groups that became separate breeding populations. Each individual in the population possessed its own variations. Each separate breeding population went on its own evolutionary path, with the separate environments selecting out different traits. Over many, many generations the separate groups became more and more different. Finally they became completely different species, evolving into the two species as we know them today.

Enrichment

Libraries should provide the resources you need to examine the areas of your choice. These resources may include books, magazines, and periodicals. In addition, major newspapers may contain articles which may discuss topics in science. Newspaper articles may be particularly useful for question 3.

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Module 2

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